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Commission on Science and Technology for Sustainable Development in the South

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EDITORIAL

The developing countries are facing a number of developmental challenges. There is no doubt in the fact that every challenge has a hidden opportunity, and conversion of a particular challenge into opportunity is the real task. Before going into the research and innovation, identification of common challenges and their understanding is the very first step towards development. COMSATS has a clear vision that development led by science and technology is the only way forward for developing countries to make their future prosperous and sustainable. It is very important to understand the avenues of development that have led the now developed world reach where they are now. For that matter, flow of information, knowledge and best practices from the developed countries is essential in order to understand how the developed world has progressed facing the challenges similar to those now being faced by the developing countries.

Science Vision, the scientific journal of COMSATS, is a humble effort to share important scientific information with a view to:

- Developing an understanding among the scientists from the developing world on similar problems with likely scientific solutions;
- Helping the scientists from the North to understand the emphases and struggles of scientific activities of their counterparts from the South.

To achieve this, the journal invites inputs from researchers, scientists and policy makers who know their roles and responsibilities towards the society and community and can make the much needed contributions in this regard. The journal is distributed internationally free of cost to all focal points of member states, the institutions in COMSATS International Network of Science and Technology Centers of Excellence and other scientific organizations. The journal is also distributed to the relevant ministries of Member States of COMSATS and their respective embassies in Pakistan, as well as COMSATS' partner institutions.

The current issue of Science Vision comprises of papers on different topics of great importance to developing countries, including environmental safety, oxidation due to ultrasonic rays, technological innovation, development of enhanced production technologies for additives, industrial applications of natural compounds, sustainable development goals, and carbon dioxide emission and its impacts. It is hoped that the authors' inputs would be of value to scientists and researchers holding this issue of the journal.

COMSATS is continuously making efforts to enhance the quality and usefulness of this journal. For this purpose, we welcome intellectual contributions from scientific communities around the world in general and the COMSATS' community in particular, in the form of high quality articles about science and technology to resolve development and socio-economic issues.

The hard work of COMSATS' team for finalizing this issue of the journal is duly acknowledged and appreciated.

Tajammul Hussain
(Advisor Programmes)

SCIENCE VISION

Patron and Editor-in-Chief: Executive Director COMSATS

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SAFETY ISSUES IN REGIONS WITH HIGH LIGHTNING OCCURRENCE DENSITY

Chandima Gomes[*†], *Ashen Gomes*[*] *and Munir Ahmed*[**]

ABSTRACT

Lightning is a major safety issue in many regions with high lightning ground flash density. However, due to the rapid development in communication technologies and high level of public awareness, lightning threats in developed countries have been reduced notably during the last few decades. On the other hand, the number of lightning related deaths and injuries in developing countries, as reported in recent studies, is significantly high. In this paper, we discuss and analyze lightning safety guidelines suitable for developing countries with high risks of lightning hazard. Formulation of safety awareness campaigns for such countries is also addressed in detail. Safety tips and programs are proposed for both domestic and workplace environments. For bound-communities, a hierarchy of hazard control has been proposed to implement distributed responsibility scheme. Such information is essential for management of lightning safety programs and reduction of risk.

Keywords: *lightning protection, human safety, awareness campaigns, natural hazards.*

1. INTRODUCTION

Lightning is a natural hazard that takes the lives of scores of people every year. As per several reports, the total number of lightning related deaths in the world may be as high as 24,000 per year. The number of cases of injuries (those who do not succumb to their injuries) may be 10 times more than the death toll (Holle and Lopez, 2003). Gomes and Kadir (2011a) showed that it is not only the isokeraunic level (thunder days per year) or lightning ground flash occurrence density of a given region that accounts for the annual number of lightning victims in the region. Population density, literacy rate, urban-rural ratio, social and cultural behaviours, poverty index and landscape topography are additional parameters that influence the lightning accidents of human beings.

Furthermore, as the public accessibility to communication systems and mass media spreads into the remote areas of a country, news regarding lightning accidents reach outside world rapidly and efficiently (Gomes and Kadir, 2011a). Thus, the number of lightning incidents may show an apparent increment in the past few decades, specifically in the regions where modernization has been started recently. Thus, analysis of the causes and patterns of lightning accidents is a complex task, especially in regions with high lightning ground flash occurrence density.

Due to various reasons actual lightning incident statistics are hardly available in many parts of the world. However, several countries have been monitoring lightning incidents for several decades. Out of them, USA has the best documented chronological record of lightning accidents, even state-wise, for the last century (Ashley and Gilson, 2009; Curran, et al., 2000; Holle, 2009, 2010; Holle, et al., 1995, 1999, 2005; Holle and López, 2003; Lengyel, 2004; López and Holle, 1996, 1998; Lopez, et al., 1993; Roeder and J. Jensenius, 2012). The long-term lightning data analysis in USA shows a noticeable decrement in the lightning related deaths with time. During the 20th Century, the lightning related deaths were reduced from about 60 deaths per ten million per year (dptm yr^{-1}) of population to less than 3 dptm yr^{-1} (Cooper, et al., 2007; Lengyel, 2004). The transition from rural to urban by a majority of the population, conversion of a substantial number of residences from small cottages built from soft materials (wood, thatch, clay, etc.) to large buildings made of hard materials (reinforce concrete, solid bricks, etc), easy accessibility to meteorological information and notification of warning, increment in literacy rate and comprehensive awareness programs launched in many parts of the country were indicated as the prime factors that contributed to this reduction in lightning accidents (Holle, 2008).

As it has been shown by Gomes, et al. (2011), Gomes and Kadir (2011a), Mary and Gomes (2015, 2012), Lubasi, et al. (2012), the number of lightning deaths were much higher in rural areas where the literacy rates are low (in South Asia and Africa where those studies have been conducted). The rural people in most of these regions live in small huts made of natural fiber, wood and clay. They hardly get access to warning information or safety awareness knowledge hubs, thus the conclusions of Holle (2008) regarding the declination of lightning accidents in USA is justified.

Australia has also developed a significantly large database on lightning hazards gathered for many decades (Golde and Lee, 1976; Coates, et al., 1993). The annual lightning related deaths in Australia has been gradually reduced from a staggering maximum value of 210 dptm yr^{-1} in the 1820s to 1 dptm yr^{-1} in

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1980s. Canada also shows a significant reduction of deaths over the time with a maximum death rate of 36 dptm yr^{-1} in the 1920s to 3 dptm yr^{-1} in the early 2000s (Hornstein, 1962; Mills, et al., 2006).

In Europe, lightning has not been considered as a grave natural hazard as the annual death rate is most often less than 10 dptm yr^{-1}. A 12 year study in Greece (1990-2001) shows that the variation pattern of lightning deaths is not consistent. During this period a minima of 1 dptm yr^{-1} have been recorded in 1998 and 2000 whereas the maximum of 10 dptm yr^{-1} has been recorded in 1999 (Agoris, et al., 2002). In the following 10 years another erratic pattern of the death rate could be observed with peak value of 8 dptm yr^{-1} was recorded in 2003, whereas no death were reported in 2005, 2007 and 2008 (Peppas, et al., 2012).

A seven year study in UK (1993-1999) reveals that the average death rate is about 0.5 dptm yr^{-1} with maxima and minima being 0.2 dptm yr^{-1} (1995 and 1997) and 1 dptm yr^{-1} (1994 and 1996). In France, the death rate has been reduced from 32 dptm yr^{-1} in 1830s to 3 dptm yr^{-1} in 1990s (Flammarion, 1904; Gourbière, 1998). Sweden records approximately 2 dptm yr^{-1} in 1980s (Eriksson and Örnehult, 1988). From year 2000 to 2009, Austria has recorded a death rate of 1.4 dptm yr^{-1} on average (Kompacher, et al., 2012). In early 90s Switzerland and Germany recorded lightning related deaths as 3.5 dptm yr^{-1} and less than 1 dptm yr^{-1} respectively (respective Federal Office statistics). More details in this regard can be found in Doljinsuren and Gomes (2015).

In South and South East Asia, Africa and South America such information is scarce except for few isolated studies (Castle and Kreft, 1974; Virenque and Laguerre, 1976; Chao, et al., 1981; Pakiam, et al, 1981; Gomes, et al., 2006 a,b; Lubasi, et al., 2012; Mary and Gomes, 2012; Mulder, et al., 2012). The statistics given in these papers are most often under estimations due to the lack of facilities and modes of collecting data efficiently. Still, the figures are much higher than those in USA and Europe.

Zimbabwe recorded 108 dptm yr^{-1} in the early 70s (Castle and Kreft 1974; Virenque and Laguerre, 1976). Sri Lanka recorded nearly 25 dptm yr^{-1} in 2003 (Gomes, et al., 2006 b). Singapore has a maximum figure of 35 dptm yr^{-1} in late 1970s (Pakim, et al., 1981; Chao, et al., 1981). In Uganda the death toll raised to 30 dptm yr^{-1} in 2011 with 19 deaths recorded by a single lightning (Mary and Gomes, 2012). Although, annual data is not available, reports in Bangladesh, Pakistan, India and Zambia reveals that almost every year there are single incidents reported in these countries during which the death toll exceeds the total annual deaths of most European countries (Lubasi, et al., 2012; Gomes, et al., 2006a,b; Gomes and Kadir, 2011a). Being a developing country, India records quite a low value of death rate; 2.5 dptm yr^{-1} (Singh and Singh, 2015) which could be attributed to the large population of the country of which a significant fraction may be living in areas of extremely low lightning ground flash density (Kuleshov and Jayaratne, 2004).

Lightning death details in selected countries have been summarized in Table-1 where most information

Table-1: Number of deaths reported in several countries per year normalized to 10 million of the population

Reference	Country	Number of deaths per 10 million per year (dptm yr^{-1})
Cooper, et al. (2007)	USA	3
Coates, et al. (1993)	Australia	1
Mills, et al. (2006)	Canada	3
Peppas, et al. (2012)	Greece	3
Gourbiere (1998)	France	3
Eriksson and Ornehult (1988)	Sweden	2
Kompacher, et al. (2012)	Austria	1.4
Elsom (2001)	UK	1
Virenque and Laguerre (1976)	Zimbabwe	108
Gomes, et al. (2006b)	Sri Lanka	25
Pakiam, et al. (1981)	Singapore	35
Mary and Gomes (2012)	Uganda	30
Doljinsuren and Gomes (2015)	Mongolia	15.4
Singh and Sigh (2015)	India	2.5

has been adopted from Doljinsuren and Gomes (2015). The table shows that even with limited information available one may clearly conclude that the number of lightning accidents in developing countries is markedly higher than that in developed countries. Chronological data in several developed countries show that the number of fatal lightning accidents is in a declining trend for the last many decades. In countries such as USA, the decimation is almost exponential. Unfortunately, there is no such information to infer any conclusions on the lightning accident trends in developing countries.

There were several efforts taken at international level during the last few years to address lightning safety issues in the developing world, especially in countries with high risk of lightning accidents. The International Roundtable on Lightning Protection, which was held in Colombo, Sri Lanka, in 2007 (Arora and Gomes, 2008), the formulation and endorsement of "Colombo Declaration on Lightning Safety" (Colombo Declaration, 2007), International Symposium on Lightning Protection which was held in Kathmandu, Nepal in 2011 (Sharma, 2012), African Regional Conference on Lightning Protection in Entebbe, Uganda in 2013 (NAM S&T Newsletter, 2013), & International Symposium on Strategic Interventions to Mitigate Hazards of Lightning, in Lusaka, Zambia, in 2015 (NAM S&T Newsletter, 2015) are few such events. Several positive steps for the way-forward have been taken in these programs; however, during the discussion sessions many stakeholders cited that the lack of compiled information on lightning safety awareness programs conducted in developing regions as a main obstacle in optimizing new programs (authors were stakeholders).

In the above backdrop, a comprehensive summary on the success and failure of lightning safety in regions with high lightning risk is a need at present for the benefit of lightning safety promoters, especially in developing world. Furthermore, such information will be very useful for the safety module developers and funding agencies in developed countries, in order to strategize their road maps, preparation of work plans and decision making on prioritizing fund allocations. This study is done with the view of filling this void in the field of lightning safety.

2. INFORMATION AND DISCUSSION

2.1 Lightning Threat

Lightning may affect human beings and animals in several ways. There are five well known primary mechanisms which accounts for most of the injuries. They are direct strikes, side flashes, step potential, touch potential and upward leaders (Cooper and Holle, 2010; Cooper, et al., 2008; Kitagawa, et al., 1996; Mackerras, 1992).

There are secondary causes of lightning related injuries such as:

a. burning of surrounding materials due to high elevation of temperature (Krawchuk, et al., 2019; Lubasi, et al., 2012);
b. discharge of toxins or smoke from burning materials (Elsome, 2001; Celiköz, et al., 1996; Holle, 2012);
c. explosion of components and materials due to shock wave and fire (Tibesar, et al., 2000);
d. drowning in water due to momentary paralysis caused by step potential (Agoris, et al., 2002; Holle, 2007);
e. missiles created by splits and fragments (Elsome, 2001);
f. falling of detached materials from buildings and trees (Cooray, et al., 2007; Elsome, 2001; Holle, 2012);
g. shockwave that may damage eardrums and skin and also cause falling of victim from higher elevations (Cooray, et al., 2007; Tibesar, et al., 2000; Graber, et al., 1996; Chandimal and Gomes, 2012);
h. intense light that may cause optical damage (Gourbiere and Lapeyre, 2002; Norman, et al., 2001; Espaillat, et al, 1999; Noel, et al., 1980); &
i. sound, distorted environment (e.g. death of people and animal) and pain of injuries that may cause psychological effects (Cooper, 1980; Cooper, et al., 2007; Panse, 1975; Cooray, et al., 2007).

Educators and community workers in developing countries are at a distinct disadvantage as they do not get opportunities to access up-to-date knowledge or training in lightning safety measures. Furthermore, the awareness promotion methodologies and techniques of imparting knowledge, practiced in developed countries, may not be applicable directly in developing countries. As an example, the web based lightning safety guidance and training which has shown fruitful results in developed countries such as USA and Australia, has not been a very successful technique of educating the public in many of the third world countries up to now (Jayaratne and Gomes, 2012). However, such conditions may change in the next 5-10 years, as the computer literacy among the common people is raised to a higher level.

Lightning safety programs developed for any region should consider minimizing the effects of each of these mechanisms of injury. However, in different parts of the world different types of injuries dominate as per the analysis of injury statistics (Mary and Gomes, 2012; Gomes, et al., 2006; Holle, 2009, 2010).

People in following environments should be given priority in the process of developing lightning safety promotion modules.

i. Live in areas of high lightning ground flash density;
ii. Permanently reside at elevated locations (hill tops, plateaus, etc.), exposed areas (large landscapes with low-grown or no vegetation, rivers, etc.);
iii. Permanently reside in unprotected wooden, thatched and clay huts, small shelters with metal roofing on non-metal structures and canvas/ polythene tents, etc.;
iv. Often involved with outdoor activities for employment (farmers, fishermen, power and communication line repairers, outdoor labourers, etc.);
v. Often involved with outdoor recreational activities (cycling, hiking, golfing, boating, adventure walking, etc.);
vi. Reside or work at locations (indoor or outdoor) close to metal transmission or communication towers.

2.2 Sheltering under Thunderstorm Conditions

In the event of a natural random atmospheric phenomenon such as lightning, no place is 100% safe or having zero risk, however, some places are safer than others. Therefore, in the event of an approaching thunderstorm one should seek shelter in a low-risk location which is reachable within a reasonable period of time.

One of the safest locations during a thunderstorm is inside a substantially constructed building, preferably with steel reinforcement (concrete slabs and pillars reinforced with steel), plumbing and electrical wiring with a sound grounding system. Such structures are residential complexes, fully enclosed factories, shopping malls, cinema halls, schools, office buildings, and private residences made with brick, concrete etc. If lightning strikes the building, the steel bars, plumbing and wiring will conduct the electricity more efficiently than a human body. Therefore, chances of lightning current entering the human body through an electric spark from the roof or walls is negligibly small. The risk is further reduced if the building is installed with a properly designed structural protection system. Design and installation of a lightning structural protection system should be done by a competent engineer specialized in the subject. Such design descriptions are given in national and international standards (IEC 62305, 2010; NFPA 780, 2014; AS/NZS 1768, 2007, etc.).

When one is inside a building, he should stay in the middle of a room or a hall. It is advisable to sit on a chair or bed and keep the feet up. If one is in standing position, he should keep his feet close together. One should never sleep on the floor, especially inside a risky building, when thunder is roaring around. One should stay inside for at least 30 minutes after hearing the last thunder. Once lightning strikes a structure, the current is most likely to flow along metal parts such as railings, fences etc. Therefore, touching or staying very close to such components should be avoided.

A structure made of non-metallic materials or having large exposed areas is not safe during a thunderstorm. The risk of injuries and death will greatly be increased if such structures are covered with combustible material (eg. wood, paper pulp, thatch, polymeric materials such as PVC or rubber, fabrics etc.) The following structures fall into the above categories, thus offer no safety from lightning. One must refrain from seeking shelter in structures under thunderstorm conditions such as:

- Thatched roofed houses or temporary shelters;
- Wooden or non-metallic structures with metallic roofs;
- Beach shacks and cabanas;
- Camping tents and picnic huts (irrespective of the material);
- Sports pavilions and open stages;
- Carports (especially the ones having no walls);
- Rooftop terraces (even when the terrace is covered with glass or transparent polymeric materials);
- Structures with no walls or half walls (Dharma-Shala of most of the temples, most of the schools in rural areas (even in urban areas), and public gathering places such as Praja-Shala etc.).

One should not stay inside a building (even if it does not fall into the above categories), which stores (or manufactures) fireworks, gun powder, explosives, volatile fluids, poisonous or compressed gases, petrochemicals etc., if the building is not installed with a structural protection system that is in compliance with national or international standards. The relevant

government authorities should take strict measures to ensure that such structures are comprehensively protected against lightning, in order to safeguard the occupants and neighbourhood.

It should also be emphasized that structures with metal roofs are very much likely to attract lightning. If the roof is fixed on a structure which is not properly earthed, the occupants will be at a very high risk of getting side flashes if the structure is struck by lightning.

If no proper building is available for sheltering under lightning conditions, then an enclosed sturdy metallic vehicle such as train, car, van, bus or large ship makes a good alternative. However, convertible vehicles offer no safety from lightning, even if the top is covered with the foldable flap. Other unsafe vehicles during lightning storms are those which have exposed parts such as open cabs, golf carts, tractors, trailers, three wheelers, motorcycles and bicycles, agricultural vehicles, construction equipment such as cranes and elevators, canoes, and open boats etc. Inside a ship, one should refrain from staying in open decks.

Inside a vehicle, one should keep the windows up, and avoid contact with any conducting paths leading to the outside or connected to the body of the vehicle (e.g. radios, body-fixed telephones and key in the keyhole etc.). One should also avoid leaning against the metal parts of the vehicles. If lightning strikes in the close vicinity, one should cover his ears with hands if a suitable ear protector (earphones, cotton buds etc.) is not around.

2.3 Lightning Threat from Equipment

Power and communication lines are frequently struck by lightning due to their exposure to lightning. When such service line is subjected to lightning, the current may travel along the wires and enter nearby buildings. Therefore under thunderstorm conditions, electrical appliances should not be handled if they are connected to the power supply or communication line. For the safety of the equipment they should be kept plugged off from the service lines. It is also advisable to remove the external antenna jack of the Television and place it outside the building. However, it should be emphasized that the unplugging of TV antenna jack, power connection, telecommunication connection etc. should be done well in advance. Such removal should not be done after the arrival of the thunderstorm.

Corded telephones and wired microphones should not be used unless it is an emergency. However, there is no additional lightning threat of using mobile phones, cordless phones or FM microphones. Nevertheless, it should be noted that the person who handles the electronics of the public addressing system is at a risk of getting a shock if the system is connected to the electricity service. Working on computers is also dangerous if they are connected to communication and electrical services. If the trip-switch (RCD) or other circuit breakers get switched off under thunderstorm condition they should be kept at off-position until the storm is over. One should also not attend for the rectification of faulty conditions in the electrical wiring system or corded telephone systems during the thunderstorm period.

If the budget permits the building should be fitted with a system of coordinated surge protective devices. Selection and installation criteria is given in many international standards, manuals (IEC 62305-4, 2010; IEEE C62.41, 1991; ITU-T REC K.21, 2005; ITU-T REC K.20, 2003) and in some literature on easy guidance (Gomes, 2011).

2.4 Dangerous Acts Indoors

There are many domestic activities that one needs to suspend in the event of an approaching thunderstorm. There are many reported lightning accidents show that hazards could have been avoided if victims have suspended activities that they were involved with. Most often, people are reluctant to give up their activities either due to ignorance/stubbornness or financial/opportunity cost.

The repairing of leakage in the roof under overcast conditions should strictly be avoided. One should not take a shower or bath or use a hot tub during an intense thunderstorm. Using the swimming pools (both indoor and outdoor) should also be avoided during the entire thunderstorm period even if the building is installed with a structural protection system. The shock wave and the intense light generated by a close-by lightning and the small step potentials that can be developed by the lightning current injected into the nearby earth, may temporarily paralyze the person who uses the swimming pool, thus drowning him to death.

2.5 Outdoor Safety Measures

It is important to plan the outdoor activities in advance during the lightning season to avoid being caught up in

a thunderstorm before reaching a safe shelter. The lightning season or seasons of a country depends on its geographic location. For an example, in Sri Lanka the acute lightning seasons are the inter-monsoon periods; March-April and September-October (however, during the last few years the occurrence of lightning has become rather erratic and spread all over the year). During the acute lightning seasons most of the thunderstorm activities take place in the evening. Therefore, one should keep an eye on the weather forecast and plan his outdoor activities accordingly.

If a person becomes a tall protrusion in a certain landscape his body may be the unfortunate object that sends the first upward channel that meets the downward stream of charge from the cloud. Therefore, in order to avoid being subjected to a direct lightning one should not expose himself to the down coming stepped leader.

Under thunderstorm conditions people should not stay at high risk areas such as:

- Playgrounds, racing tracks and other outdoor recreational areas;
- Paddy fields and other agricultural landscapes including gardens with low growth;
- Beaches, river banks, open wells, bridges and open roads;
- Open construction sites, work sites and aerodromes, etc.;
- Higher elevations such as mountain tops, and building tops, etc.;
- Close to isolated trees and other tall isolated objects.

To avoid such places, one should obviously refrain from playing out door games and doing recreation activities, farming, boating, cycling and riding, hiking, gathering for open rallies, repairing power and other service lines, etc.

One of the most important rules of outdoor lightning safety is to avoid seeking shelter under large isolated trees during thunderstorm periods. The electrical resistance of a human body; about 300 Ohms is much less than that of a tree which is in the order of mega Ohms. Therefore, once a tree is subjected to a lightning strike the large current that is flowing along the tree trunk may jump to the bodies of the people who gather around the tree and passes into earth in a low resistive path. This side flashing may kill even 5-6 people, according to the records that are available from Sri Lanka, Bangladesh and Pakistan, etc. (Gomes and Kadir, 2011a). Although sheltering under isolated trees are very risky under thunderstorm conditions, in comparison with open terrains or mountain tops, seeking shelter in a uniformly grown forest patch or clumps of shrubs may be less dangerous.

When one is in contact with an object which will be subjected to a lightning strike a part of the current may flow across his body as well. This has been described earlier as the touch potential. In order to prevent the body being subjected to touch potential one should keep away from flag poles, metallic masts, wire fences, metallic walls and doors, metal railings, etc.

One should also avoid taking bath in open pools, streams, rivers, lakes, sea etc., under thunderstorm conditions. A person may be drowned to death if he falls unconscious in an unattended environment while he is taking a bath or swimming in such water masses (even if the water is only a couple of feet deep). One should also discontinue fishing, water skiing, scuba diving, swimming or other water activities when there is lightning or even when weather conditions look threatening.

If one is in a small watercraft such as a boat, canoe, raft etc., move fast as possible to the land and seek a proper shelter. In the event that such movement is not possible, try to take shelter under a bridge. In the worst scenario, be inside the cabin or any other enclosure if such location is available and take the safety position that will be described latter. It is highly recommended that those who regularly use small to medium sized boats should adopt proper lightning protection systems in the watercraft. A low-cost protection system for small boats is given in Gomes, et al. (2012). If one stays close to a tall communication or broadcasting tower he has to take extra measures in protecting himself and his equipment. This is due to the high chance of lightning current flowing near to his house or factory. In case of poor earthing at the tower base there can be a so called “earth potential rise” in the nearby area, so that a person outside may be subjected to a “step potential” (Gomes and Diego, 2012). As a result, he may be injured or temporarily paralyzed. Such paralysis may lead to severe injuries and even death if he is standing close to a pit or unprotected well or taking a bath in a water pool. Thus, those who have such towers in the neighbourhood should strictly be adhered to the safety guidelines described in this paper. In addition to human and livestock injuries, there is a high probability of equipment damage in buildings in the neighbourhood

such towers both due to ground potential rise and induced voltages (Chandimal and Gomes, 2012).

2.6 Estimation of Timing

In many countries such as USA, Canada and Australia lightning safety plans essentially include the so called 30/30 rule (30/30-R). As per the 30/30-R people should get into a protective shelter (sturdily built building or a all-metal vehicle) if the illumination-to-thunder time-delay (duration of time in seconds between the vision of the lightning flash and the subsequent hearing of thunder) is 30s or less and that they should not leave their shelter of protection until 30 minutes after the final sound of thunder.

As light travels almost instantly compared to the speed of sound (approximately 330 m/s), a 30s time-to-thunder corresponds to a lightning about 10 km away. The analysis of lightning detection data in several countries shows that at the beginning of the lighting activity, strikes can be scattered within a space of about 10-15 km (Christian, et al., 2003). Hence, at least 30s time-to-thunder lead is necessary prior to the arrival of thunderstorm as there is a possibility of distant strikes. A 30-minute time delay, after the sound of last thunder, is required as the trailing part of thunderstorms may carry a net residual charge either in the negative charge centre or in the positive charge centers. This charge may produce lightning on the passing edge of a storm, tens of minutes after the rain has ended. Note that in a thunderstorm, rain is produced typically from the cloud base, which may be quite small in coverage compared to that of the upper parts. However, there is no solid scientific evidence to justify the validity of 30 minute delay from last sound of thunder to restart the normal activities.

Several studies have revealed that most people affected by lightning are struck not at the most active stage of a thunderstorm but before and after the storm peak. This can be explained scientifically as in many cumulonimbus clouds that produce lightning, the anvil of the cloud from which lightning can be emanated, is several tens of kilometers shifted from the rain base due to the wind shear. Most importantly this part of the thundercloud houses positive charge that drives positive cloud to ground lightning. As per the literature (Cooray, 2015) such positive lightning may drive much larger impulse currents (in the order of 500 kA) and long continuing currents (currents in the order of about 1 kA flowing for a considerably longer period). Furthermore, if the lightning strikes before the rain the chances of triggering fire is also larger due to the dry conditions that may prevail. Therefore, such lightning poses a much higher threat to the human beings, animals and property than their negative counterparts.

The above facts show that many people are unaware of how far lightning can strike from its parent thunderstorm. Therefore, one should not wait for the rain to start seeking shelter and should not leave shelter just because the rain has ended.

Figure-1: Safety position in the event of a severe thunderstorm (if you are caught outdoor). Squat down and duck your head. Close the ears with palms to protect them from the bang due to close lightning. Wearing footwear such as shoes with rubber, PVC, leather soles, etc., or rubber slippers may be advantageous (to minimize hazards due to step potential; but not to prevent or even reduce the chances of getting direct strikes).

Although, application of 30/30-R is successful in developed countries such as USA, Canada and Australia, the same may not be the case in many developing countries, especially in communities that work on daily wage basis. As per the outcomes of interviews conducted by authors in Bangladesh and Sri Lanka, a majority of low-income society are not ready to give up or delay their professional activities for more than 5-10 minutes, even though they have an understanding of the risk they pose (experience of authors in the two countries during the awareness programs conducted). Hence, a suitable rule or guideline should be adopted region-wise to replace 30/30-R, if it is practically nonviable in a given region.

2.7 Safety Position

If one cannot go elsewhere and is compelled to stay outdoors in a severe thunderstorm (as he may be far away from a proper shelter), he should move to the safest location available (away from open fields, higher elevations, water, etc.) and adopt the safety position described below.

The person should crouch down, put the feet together and place hands over ears to minimize hearing damage from thunder and duck the head as much as possible (Figure-1). One should make sure that he does not take the safety position at a place that has a chance of falling material (very close to a large wall or underneath an overhanging roof), flooding (dry river beds, floodplains, pits, etc.), land sliding (eroded slopes, newly filled lands and close to wells, etc.) or explosion (close to underground ammunition dumps, minefields, etc.).

Each person in a group, in safety position, should at least be 3 m away from one another, thus if one unlucky person is struck, the others are protected and can provide first aid to the victim.

In the event of very close thunder activities, one better not use earphones and headsets. All removable metallic parts on the body such as backpacks, caps with metal tips, wrist watches, metallic badges etc. and any metallic items such as golf clubs, fishing rods, agricultural tools, tennis rackets, umbrella etc. should be removed or dropped aside. The reason for getting rid of such metal objects is to avoid getting side flashes and also to prevent heat being trapped into a single point in the event of a lightning strike to an unfortunate person. There are several records where people have been severely injured as metal parts on the body garments were melted due to the heat of the lightning current and stuck into the body. However, one should note that there are no scientific evidences to conclude that metal parts attached to the body have any influence on the probability of direct strike to a human being.

It will be advantageous to wear shoes or slippers made of insulation material (such as rubber, clothes, leather, plastic, etc.), as that will minimize the effects of being subjected to step potential. Studies that have been done in Bangladesh reveal that step potential may lead to the death of people more often than one would expect (Gomes, et al., 2006b). It should be repeated that such footwear also has no influence on the probability of the person being subjected to direct lightning strikes.

2.8 Safety at Workplace

Lightning safety should be an integral part of the safety plan of workplaces in areas of high lightning occurrence density. This is specifically important in the industrial and service sectors where

- considerable outdoor activities are involved; power distribution, communication (tower related sites, line maintenance etc.), building construction, road and other civil constructions, defense, police, dock yards, transportation, airport and aviation, hydro projects, fisheries, plantations, metal crushers, playgrounds, Golf courses, swimming pools, etc.,
- large masses of employees are engaged; garment industry, hotel industry, hospitals, etc.,
- a high risk environment exist; fire work industry, explosive manufacturing, petrochemical industry, compressed gas distribution, etc.

The employees of such sectors should be given a mandatory short training program together with demonstrations on lightning safety and protection on annual basis. Typically a three hour program will be sufficient to enlighten the awareness of workers. Such training program should include:

- basic concepts of lightning;
- human safety concerns;
- techniques of lightning protection of equipment and properties;
- training on first aid, and
- maintenance and record keeping, troubleshooting and regular inspection.

The following measures can be taken to improve the lightning safety environment of the workplace:

- Installing of proper structural and surge protection systems to the buildings.
- Displaying of "do"s and "should-not-do"s under thunderstorm conditions, at frequently-visited places of employees; restaurants or lunch/refreshment rooms, reception, rest rooms, recreation centers, etc.
- Installing of lightning warning systems at vulnerable places.
- Displaying of warning signs at dangerous locations, such as playgrounds, swimming pools, outdoor recreation centers, beaches, isolated trees, open spaces, flag poles, close to down conductors of the structural protection system, etc. Few such warning signs are:
  - "Do not use XX under lightning conditions". XX: Playground, swimming pool etc.
  - "Keep away from this XX under lightning conditions". XX: flagpole, down conductor, tree etc.
  - "Don't go out of the building under lightning conditions". In beaches, gardens, hotels etc.
  - It is highly meaningful to incorporate these warning signs (displayed in both English and native languages) with a lightning warning system.
- Covering of the locations of the earthing pits (of down conductors or power) with a few centimeter layer of gravel or crushed rock (area of radius about 2 meters around the pit).
- Planning of outdoor events such as repairing of power and communication lines, plantation activities, construction work etc, according to the weather forecast or information obtained from a lightning detection system. This is specifically important in the case of repairing power systems where a lineman is lifted by an insulated-boom crane to be in contact with low voltage or high voltage overhead lines. As far as the bucket is insulated from the body of the crane (and in most cases the bucket is temporarily bonded to the line as well) the lineman is safe from electrocution due to power frequency currents. However, in the event of a lightning strike to the line, the bucket will become a floating electrode that facilitates the lightning current to flow into ground in the form of aerial spark-resistive flow combination. In other words a lightning generated spark may leap through the insulation of the bucket (bridging the gap electrically) so that the lightning current may pass through the body of the lineman into ground (killing or injuring him).

2.9 Organized Lightning Safety Promotion

Lightning safety has been promoted at various levels by individuals and organizations in South Asia for several decades. However, due to the disorganized manner that such programs have been conducted, the maximum benefits of the investment and efforts could not be harvested (Jayaratne and Gomes, 2012). Observations of authors in Bangladesh, Sri Lanka and India reveal the following shortfalls of disorganized and unplanned lightning awareness campaigns.

a. *Overlapping of target groups:* There were occasions that the same village or same school has been approached by multiple organizations for the lightning safety programs. This is often observed following an occurrence of a catastrophic incident in a given area. Repeated programs of similar type may wear out the audience and deprive other parts of the community acquiring awareness.
b. *Overlapping of safety promotion modes:* Similar media programs, quiz competitions and seminar series etc. at the same time in a given region may be less effective.
c. *Lack of opportunities for background studies:* It is very important to do the success-failure analysis of previous programs prior to the launching of similar programs in a given region.
d. *Difficulties in validating program outcomes:* It is much easier to evaluate success-failure rates of programs when data can be shared through collaboration.
e. *Lack of confidence and trust of public:* It will be quite an uphill task to build up public trust and confidence when promoters reach masses at individual or solitary organizational level. On the other hand the same task may be quite viable by approaching at organized institutional level.
f. *Promotion of inadvertent mis-information:* Lightning protection is plagued with many products and technologies that are totally rejected by international scientific community and many reputed standards due to their lack of scientific acceptability. However, vendors of these products may infiltrate unsuspecting safety promoters and include misinformation into the safety programs with the view of boosting their fraudulent products (Gomes and Kadir, 2011b).

Therefore, it is proposed to establish lightning awareness centers (LAC) in each developing country to address the needs and issues of the respective regions. Large countries such as India, China, etc.

need more than one LAC in addressing lightning safety issues in the country. The LAC in each country should develop modalities to take the message of lightning safety to the public. In different regions these modalities may be different. For examples; As per the experience of the South Asian Technology research and Information Centre (SATRIC) and the Technology Assistance for Rural Advancement (TARA), the awareness programs conducted for children at secondary school level were very successful in Sri Lanka while folk songs and street dramas on lightning safety became a very powerful awareness promotion tool in Bangladesh; but not vice versa (Gomes, et al., 2006b).

The decision-makers of each centre should plan out the best ways of disseminating knowledge and promoting awareness in each region. It is also important to share the experience of each centre with others. The following general activities have been recommended to be conducted by the regional lightning awareness centers; however, the activities should not be restricted to the given list.

- Publishing awareness material in local languages (with diagrams and pictures) and distributing them among schools, public service sectors, etc;
- Conducting lightning safety seminars and demonstrations / training on first aid for school children, social workers, etc;
- Educate the private and government sector in lightning protection techniques and the importance of industrial lightning safety;
- Displaying of banners, posters, cut-outs on lightning safety in highly lightning prone areas;
- Conducting awareness programs for community leaders such as religious heads, doctors (both western medicinal and indigenous), public servants of local authorities and officers of police;
- Training youth in the region to practice lightning protection as a self-employment (especially on low-cost protection measures).

Modes of promoting lightning safety are strongly dependent on cultural, social and economic backgrounds of a given region. Hence, it is not a good practice to use everywhere a generalized formula in developing lightning safety modules. As it is described in literature (Jayaratne and Gomes, 2012) lightning safety modules used in USA were not very successful in South Asia. Even within South Asia, modules successfully practiced in one country was not that fruitful in another country in the region (Jayaratne and Gomes, 2012).

Another point of significance is the attitudinal trends of certain nations. For an example, as it was reported by Jayaratne and Gomes (2012), In Sri Lanka, the level of awareness on lightning safety and protection among the public is quite high due to various programs conducted over the years, however, as a majority simply neglect or overlook the safety advices due to ignorance or stubbornness, lightning accidents in the country is in the increasing trend for the last decade. Jayaratne and Gomes (2102) attribute this to the decade long attitudinal practices of the island nation regarding hazard safety.

The LAC should consider these regional and local factors into account in developing awareness programs for the people within their territorial coverage.

2.10 Hierarchy of Hazard Control

A low-income society with below par literacy rate is much tougher to be mechanized for adopting lightning safety measures compared with the same operation in developed countries (Jayaratne and Gomes, 2012). However, the interviews conducted by the authors in several South Asian countries with a number of potential victim communities, revealed that many social and religious leaders are concerned about the human safety against lightning and they are willing to be educated. Such observations prompted us to develop a hierarchy of hazard control mechanism (Brdys, et al., 2008; Scattolini, 2009,) that may successfully be applied to the communities in high lightning risk regions. Although, such mechanisms are employed in enclosed work environment (factories, harbours, cargo control divisions, outdoor sites with task boundaries etc.), any community with reasonable size and common interests (fisher communities. farmers, livestock based communities, highlanders etc.) may provide the operational feasibility for such mechanism (Scattolini, 2009).

A group of people, even very large in number that engaged with similar type of employment or routine practices can be treated as a bound-community. Such community is often composed of many interacting subsystems and sub-processes. Thus, the safety of such social system with respect to any natural hazard cannot be easily ensured either by centralized control alone or individual control alone. However, the bound-nature of the community either by profession or by other mass activities makes it viable for implementation of safety measures to the community through distributed responsibility of control. A

hierarchal hazard control approach is needed for lightning safety of such community under this backdrop.

The first attempt of formulating hierarchy of hazard control was done by Mary and Gomes (2015), where they have applied the concept to the fisheries community along the shores of Lake Victoria in Uganda. In this study, we expanded this concept in a broader perspective to make the applications more generalized. Based on the inferences and recommendations given in previous sections, the following hierarchy of control map is proposed for the lightning safety of a bound-community, as shown in Figure-2. Such bound communities should have a common parameter that integrate them into similar practices or activities; e.g. by profession (fisheries, farming, outdoor construction, mining, highway cleaning, etc.), by social and religious norms (congregation, pilgrims, outdoor rituals, mass rallying etc.) and by recreational activities (group hiking, outdoor sporting, amusement and adventurous activities, etc.).

Forecasting: The government (through Department of Meteorology) or a relevant private sector that owns region-wide lightning detection system should provide thunderstorm forecasting and lightning nowcasting information to the concerned community. This should be done in collaboration with mass media, especially audio-visual media such as radio and television. Even electronic media such as internet is fast reaching even remote communities. The need of providing accurate information in local languages is a key factor to successful adoption of safety measures following such news broadcast.

Awareness: The experience in Uganda (Mary and Gomes, 2012), Zambia (Lubasi, et al., 2012), Bangladesh and Sri Lanka (Gomes, et al., 2006), shows that thunderstorm forecasting, safety guidelines, protective structures etc. have no impact on community protection unless the society is well aware of the danger of lightning and safety measures that should be taken. The promotion of awareness, even for a single community is not a once and for all process. Such promotion should be done on periodic basis. Local authorities, governmental institutions (police, educational institutes, hospitals, etc.) and non-governmental organizations may take part in this process with the help of local community leaders.

Local Control: Although a general consensus can be reached among the community to act on the thunderstorm forecasting information, in most of the cases of regular non-dramatic natural hazards, public needs local directives in starting safety procedures. Such directives or leadership are more prominently felt in low-educated societies than in their opposite counterpart. During floods in Thailand and Malaysia, and debris flow in Pakistan and Iran, it has been observed that a majority of victims haven't followed

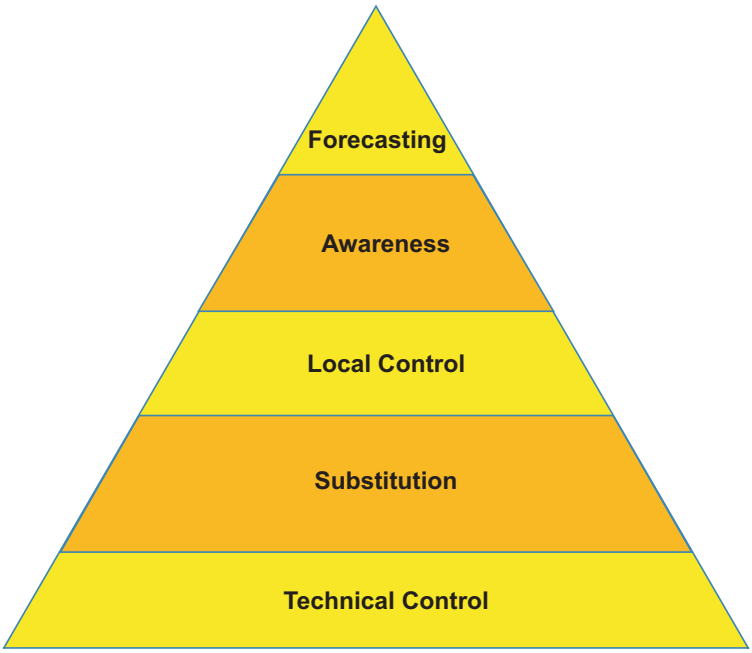

Figure-2: Hierarchy of hazard control for a bound community

even simple safety guidelines due to the lack of initiatives by local leadership. In lightning safety in a bound-community such local control can be achieved by lightning warning systems located at regular intervals in a way that they can be seen at distance. The most appropriate location for such warning system is the lake shore. These warning systems may preferably be in the form of coloured lights (Green-Red or Green-Orange-Red sequences). Alternatively large signal systems in different colours can be erected if electricity supply is an issue. However, such signal systems are invisible during nighttime. The other mode of local control is the training of group leaders on executing rules on activity stop/start (e.g., 30/30 rule) and following safety measures (e.g., avoiding shelter under large trees, going into safety position, indoor guidelines, etc.). Such group leaders may be land-lords, heads of communities, village-heads, religious leaders, teachers, responsible civil servants, doctors, police etc. The important aspect of group leaders is that the concerned group should have a natural tendency to follow the orders of such leader.

Substitution: In a low-income society it will not be that easy to prevent people from attending their bread-earning activities as such stoppage may deprive them their daily wage. Thus there should be a substitution for them during the stoppage of the work. Such substitution will highly be subjective as the alternative tasks are community dependent. One example of such substitution is to direct the farmers in an agricultural community to an indoor activity such as harvest sorting, stock taking, group discussions on weeding, etc., that can be conducted inside a sturdy structure when they are prevented from going out into the farm fields. Planning of such substitutions and providing of directives to take up the substitute work should be done by selected community leaders.

Technical Control: As a standard solution for those who seek shelter in places of low risk and a last resort solution for those who are not willing to give up their outdoor activities under any cost, lightning protection systems can be implemented and viable protection measures can be adopted appropriately. These can be implemented at community level, most probably with the help of external experts. These may include low-cost structural protection systems (Gomes, et al., 2012; Gomes and Kadir, 2015) at all buildings in the community (if possible) or at least at several selected structures where mass gathering is possible, less complicated protection system for small water vessels such as fishing boats (Gomes, et al., 2012), insisting on wearing rubber sole boots to minimize step potentials, etc. Placement of metal structures specially made for lightning protection in the farming fields, work sites etc. at regular intervals is strongly recommended as such structures could be developed at quite low cost. Properly designed such structures can be placed at several locations even at off shore locations with the aid of anchors, thus, fishermen or workers at water-based employment in unsafe boats can get inside such in the event of acute thunderstorms.

2.11 Future Trends

The future trends in lightning density and lightning accident rate may not have a clear positive correlation. Thunderstorms are generated by the rising parcels of moist air. The convective processes which lift water vapour upwards are fueled by the solar radiation. Hence, with the rise of global temperature and sea surface temperature, one can easily predict increment of number of thunderstorms per year in the world. As it is predicted by Romps, et al. (2014), the number of lightning strikes will increase by about 12% for every degree of rise in global average air temperature. The global average surface temperature was elevated by 0.6 °C to 0.9 °C between 1906 and 2005, and the rate of temperature increase has nearly doubled in the last 50 years (Hansen, et al., 2010). With these results one can anticipate approximately 10-12% increment in global thunderstorm activities in the next 100 years.

On the other hand, predicting the trends of lightning casualties is much more complicated. According to the theoretical studies done by Gomes and Kadir (2011a), lightning casualties have positive correlation with lightning ground flash density and population density, whereas it has a negative correlation with urbanization and rate of literacy. In most regions of the world all these factors increase with time in different proportions. In USA the rate of lightning related deaths has decreased almost exponentially during the last century (Holle, et al., 2005) and many other developed countries show somewhat similar trends. On the other hand India shows some increment of lightning fatalities over the years (Singh and Singh, 2015). Unfortunately, the lack of long term data prevents us making any conclusion on the fatality trends in other developing countries.

However, the fast development and rapid spread of internet through which the knowledge flows into the doorstep of developing nations and the improvement of lightning safety techniques and their technology transfer to the root levels may result decrease in lightning fatalities in the future despite increment in thunderstorm activities.

3. CONCLUSIONS

It is shown that lightning safety awareness promotion in a given region should be done in an organized institutional level to harness maximum outcomes. A safety module developed for the region should be unique to that region. Various socio-economic factors such as literacy rate, urban-rural ratio, cultural and religious practices, poverty level, professional practices etc. and environmental factors such as isokeraunic level, level of exposure of the region, housing and workplace sheltering, topology of the region etc. should be taken into account in developing the safety module. A hierarchy of hazard control has been proposed for bound-communities to implement distributed responsibility for lightning safety.

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PHENOL OXIDATION UNDER PULSED MODE OF ULTRASONIC IRRADIATION

Robina Farooq†, Fahad Mateen*, Maria Siddique**, Asad U. Khan*, Zaki Ahmad*, M. Ashraf Shaheen****

ABSTRACT

This study demonstrates ultrasound assisted Fenton oxidation of phenol present in waste water produced as a result of synthetic processes. The degradation of phenol was investigated at isothermal conditions under 20 kHz ultrasonic frequency, under pulsed and continuous mode of irradiations. The ultrasonic system was calibrated by calorimetric measurements. Various experimental conditions of H_2O_2, $FeSO_4.7H_2O$, aeration, initial pH and acoustic intensity have shown that phenol oxidation was enhanced using ultrasound at pulsed mode instead of continuous mode. It was found that optimum oxidation of phenol was achieved at 80 mM H_2O_2, $8.9x10^{-4}$ mM $FeSO_4.7H_2O$, pH of 3 and 20 Wcm^{-2} of ultrasonic acoustic intensity. Pseudo first order rate kinetics were observed at different phenol concentrations of 2 mM, 4 mM and 5 mM. A fitted regression model by R software confidently provided a tool for quantifying the main factors involved in oxidation. Multiple linear regression analyses showed that phenol oxidation is enhanced by increasing concentrations of H_2O_2 and $FeSO_4$ and reducing pH of solution.

Keywords: *Ultrasonic irradiation, fenton oxidation, sonofenton kinetics, half-life studies, regression model, phenol oxidation*

1. INTRODUCTION

The waste stream discharged by leather, textile, dyes, oil refineries, and paint industries contains substantial amount of phenol. These waste streams when exposed to ambient environment can cause severe tribulations and even minute concentrations of phenol ($<3.3x10^{-2}$ mM) are intolerable in water. Higher concentrations of phenol in water not only kill fish, but also completely act as biogenic compound (Saha, et al., 1999; Jain, et al., 2011). The presence of phenol in water bodies contributes to severe pollution and causes carcinogenic and mutagenic effects to human and aquatic life. Hence, prior treatment of phenol containing waste stream is requisite before it is discharged to environment.

Previous investigations introduced various methods for the treatment of hazardous organic pollutants from the wastewater (Berlan, et al., 1994; Pera-Titus, et al., 2004; Bremner, et al., 2009; and Babuponnusami and Muthukumar, 2011). However, biological, chemical and physical treatment processes suffer from either inefficiency, phase transfer of pollutants, or toxic end-products (Kušić, et al., 2006).

Recently, advanced oxidation processes are gaining momentum for oxidation of phenol as its oxidation is inhibited by conventional chemical and biological methods.

Advanced Oxidation: Process (AOP) has shown potential to mineralize organic pollutants, including phenols. However, AOP requires transition metals, e.g., Fe, Cu, etc. along with a large amount of H_2O_2, which themselves contribute towards pollution (Siddique, et al., 2014). The decomposition of organic pollutants occurs by its OH• radicals that are generated by H_2O_2 in the presence of ultraviolet light, ultrasound radiations or microwaves (Barros, et al., 2013).

The use of ultrasound leads to the formation of acoustic cavitation by pressure fluctuation in a liquid and the collapse of these cavitation bubbles develop hotspots with extremely high local conditions of temperature and pressure, which allow the formation of reactive radicals, such as H•, OH•, O•. Ultrasonic oxidation of organic compounds can be enhanced by using oxidizing agents. Particularly, the Fenton's reagent ($FeSO_4.7H_2O$, H_2O_2), along with the ultrasound irradiation leads to much higher oxidation efficiency in very short span (Segura, et al., 2009; Bach, et al., 2010; Luis, et al., 2009; APHA, 1998). Hence the hydroxyl radicals (2.33 V oxidation potential) formed by cavitations quickly remove hydrogen from the aromatic ring of phenol, resulting in a series of oxidation reactions to mineralization and non-toxic end-products (Bhargava, et al., 2006). Studies on sonofenton oxidation of phenol have been restricted to continuous mode of ultrasonic irradiation. However, little attention is paid to investigate sonofenton oxidation of phenol using pulsed mode of ultrasonic irradiation. During pulsed mode of ultrasonic irradiation, it was observed that the specific energy consumption is lower in the case of concentrated aqueous effluents. This trend indicates that the process is more efficient in terms of energy consumption for more polluted streams (Cailean, et al., 2014).

Therefore, the present study was performed to determine sonofenoton oxidation of phenol under various experimental conditions using pulsed and continuous mode of ultrasonic irradiation and to

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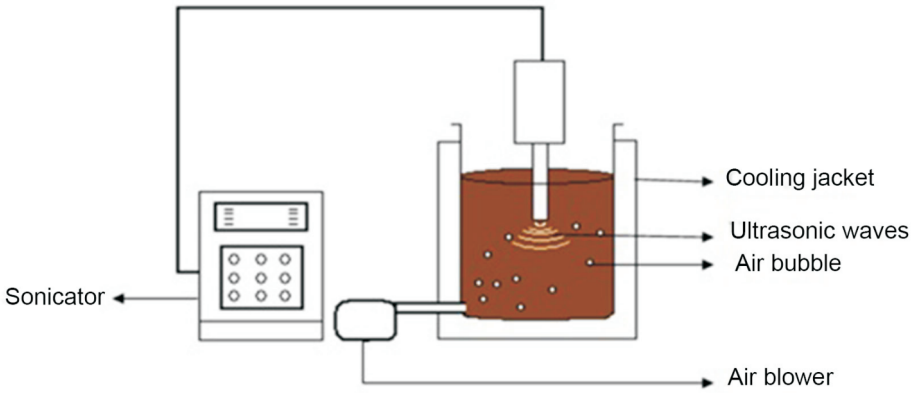

Figure-1: Experimental setup of Sonofenton oxidation of phenol

present a statistical model at optimized conditions to understand the relationships between different factors with oxidation of phenol.

2. MATERIALS AND METHODS

Sonofenoton oxidation of phenol under various experimental setups, including continuous, pulsed, continuous aerated, and pulsed aerated irradiation of ultrasound was conducted. The effect of ultrasonic intensity on phenol oxidation was also investigated. Kinetics of reactions were determined and the results were interpreted using statistical model at optimum experimental conditions. Sonofenton oxidation of phenol at continuous mode of irradiation has been investigated previously (Babuponnusami and Muthukumar, 2013; Pétrier and Francony, 1997). The present study involved the comparison of pulsed with continuous mode of ultrasonic irradiation for percentage removal, order of reaction/rate constants determination, and half-life of phenol oxidation.

Phenol and ferrous sulfate heptahydrate ($FeSO_4.7H_2O$) hydrogen peroxide (35% w/v) (H_2SO_4, NaOH) were obtained from Sigma Aldrich and NH_4OH was obtained from Merk. The aqueous solutions of phenol (2 - 5 mM) were prepared while dissolving 10-100 mM H_2O_2 and 0 - 1.0 mM $FeSO_4.7H_2O$.

Sonofenton process was carried out in 500 ml cylindered Pyrex vessel as a batch reactor and ultrasonic waves were introduced by VCX500 ultrasonic processor outfitted with a titanium horn-probe (13 mm of diameter) for continuous and pulsed wave at a frequency of 20 kHz (Figure-1). Air-flow of 1 mL min^{-1} was maintained throughout the experiments. All the reactions were performed at atmospheric pressure in isothermal condition (25±1°C) for 60 minutes.

The effect of ultrasonic power density on oxidation of phenol was probed at 0, 5, and 10, 20 and 40 Wcm^{-2} in aerated solutions. Energy input was determined (equation-1) using calorimetric method (Price and Lenz, 1993) by recording temperature increase after every every 5 minutes for 30 minutes.

$$q = mc\,dT/dt \quad (1)$$

where, 'q' is energy input, 'm' is the mass of water, 'c' is heat capacity of water, and 'dT/dt' is the temperature gradient over time. Ultrasonic power density (Wcm^{-2}) was calculated by dividing energy input over area of ultrasonic probe.

The samples were collected at regular intervals and oxidation process in samples was immediately ceased by bringing pH at 9 using 0.5 N NH_4OH for analysis. The concentration of phenol was measured on calibrated UV-Vis spectrophotometer (O.R.I Germany UV 4000 Spectrophotometer) by 4.aminoantipyrine method at pH 7.9±0.1 (Eaton, et al., 2005).

The percentage decomposition was determined using Equation-2.

$$\text{Phenol \% decomposition} = (1-C_t/C_0)x100 \quad (2)$$

In Equation 2, 'C_t' and 'C_0' are the concentrations of phenol at reaction time of 't' and '0' minutes, respectively. The change in phenol concentration was determined using Beer–Lambert Law (Shu and Chang, 2005).

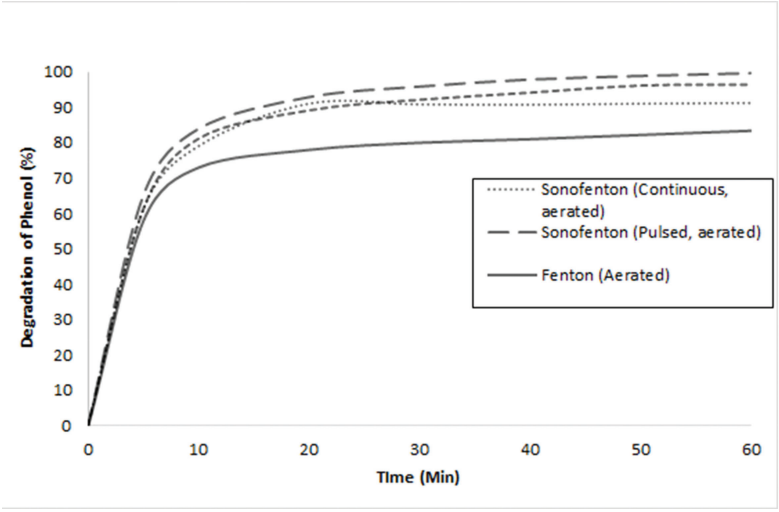

Figure-2: Effect of pulsed and continuous wave ultrasound on fenton oxidation of phenol in aerated and non-aerated systems

Preliminary experiments are conducted to find concentrations of hydrogen peroxide, ferrous sulfate and pH where maximum oxidation of phenol takes place. The optimum conditions were found to be 8 mM H_2O_2, 8.99 x10^{-4} mM concentration of ferrous sulphate at pH level 3 (supplementary data) and are kept constant throughout current investigation.

The kinetic study of phenol oxidation by ultrasound assisted Fenton oxidation in aqueous solutions of phenol was undertaken at its various initial concentrations of 2, 4 and 5 mM, while keeping all parameters constant.

A latest version of 'R' software was used for statistical modeling. Hence, the multiple linear regressions are performed to observe the effect of pH, H_2O_2 and $FeSO_2.7H_2O$ on percentage degeneration of phenol. Analysis of variance test was performed to evaluate the reliability of fitted regression model.

3. RESULTS AND DISCUSSION

3.1 Ultrasonic Irradiation and Phenol Oxidation

The oxidation of compounds in ultrasonic field depends upon three major factors, including adsorption of contaminates on its gas / solution interface, number and shielding effect of cavitations.

Sonofenton oxidation rate has significantly enhanced over fenton alone (Figure-2). This is due to increased dissociation of H_2O_2 and H_2O and formation of OH• radicals, which, in turn, are used for phenol oxidation. The volatile phenol compound may interact with the bubble-water interface and enter cavitation bubbles and react with OH• radicals in gas, interfacial, and regions of cavitation bubbles.

In an attempt to determine the ultrasound-induced oxidation efficiency of phenol, pulsed ultrasound was compared with continuous ultrasound in its aqueous solutions. The lifetime of the gas/solution interface increases during the pulse intervals which in turn increases adsorption of contaminants on chemically active bubbles. This adsorption depends on the ratio of the ultrasonic pulse length (T) to pulse interval (T_0). The ratio of the ultrasonic pulse length (T) to pulse interval (T_0), in current study was kept at 3:3. While in continuous mode, ultrasound is irradiated continuously. The effect of pulsed and continuous mode on percentage oxidation of phenol for the same parametric conditions is shown in Figure-2. During continuous mode of sonication, shielding effect of ultrasonic waves by bubbles is reported. Where size of some bubbles becomes more than their resonance size causing them to be unresponsive regarding the generation of cavitational effect (Ishtiaq, et al., 2009). Therefore, in continuous mode of sonication, some of the acoustic energy profligates into just heat, vibrations and degasification of liquid. While in the case of pulsed mode of sonication, the shielding effect is minimized as bubbles are generated below their resonance size. The high sonochemical oxidation by pulsed ultrasound, compared with that by continuous-wave ultrasound, can be due to the residual pressure amplitude during the pulse-off time and the spatial enlargement of active reaction sites. During pulsed

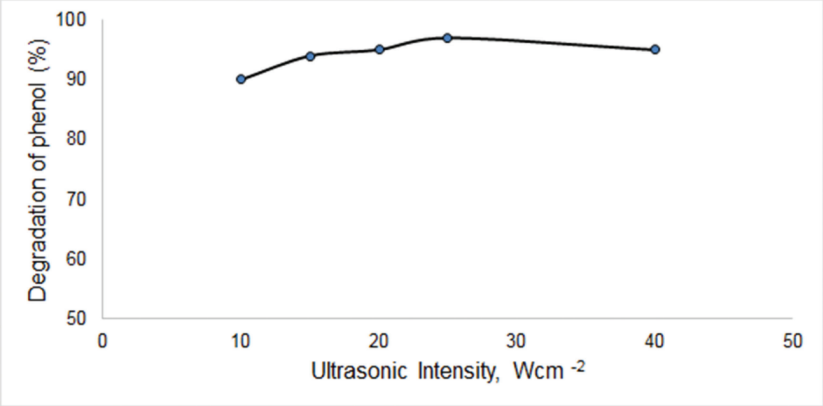

Figure-3: Effect of Power Intensity on Phenol Percentage Oxidation

ultrasound, it allows time for diffusion in bubble–water interfaces, the sources of reactivity between two successive pulses (Tuziuti, et al., 2008).

The amount of dissolved gases in solutions affects cavitational events and reaction rates. The effect of aeration in continuous as well as pulsed wave ultrasound on sonofenton process was studied at 2.5 l/min flow rate of air and was compared with non-aerated sonofenton process (Figure-2). Experimental results showed that by introducing the aeration in the system, phenol oxidation was increased. This could be explained based on the fact that air bubbles act as a nucleation site for cavitation and the number of bubbles formation might increase leading to the increase in events of bubble collapse via rectified diffusion. Moreover, bubbled air imparts an additional advantage in mass transfer increment by enhancing free turbulent fluidic movement.

The sonofenton phenol oxidation at different ultrasonic intensities at pulsed mode of operation was probed. At acoustic intensity of 25 Wcm^{-2}, maximum oxidation was achieved. Further increment in its intensity leads to decrease in phenol oxidation (Figure-3). Current study showed that maximum removal of 97% is achieved at very low intensity of 25 Wcm^{-2v} as compared to previous studies where 69.77 % removal efficiency was achieved at 40.76 Wcm^{-2} using continuous mode of operation (Cailean, et al., 2014). This can be explained based on the fact that the excessive power intensity may lead to bubble shielding effect, according to which a dense cloud of these bubbles gather around the ultrasonic transducer which ultimately decreases the oxidation rate (Chen, 2012; Cintas, 2012; Vijayanand S. Moholkar, et al., 2012).

3.2 Kinetic of Phenol Oxidation

Kinetic of phenol oxidation at its various concentrations of 2, 4 and 5 mM, apparently follows pseudo first order reaction (Figure-4). The half-life $t_{1/2}$ and regression coefficient R^2 obtained for pseudo first order reaction at different concentrations of phenol are shown in Table-1.

3.3 Statistical Model for Phenol Oxidation

A statistical model is developed for determining the effect of hydrogen peroxide, ferrous sulphate and pH of the solution on phenol sonofenton oxidation at pulsed mode of irradiation (supplementary data in Figures 1, 2 and 3). The model confidently provided quantitative information regarding the significance of these parameters and their consequence on oxidation of phenol in aqueous medium. A latest version of R software was used for statistical modeling and multiple

Table-1: Pseudo first order rate constant kobs, half-life $t_{1/2}$, and regression coefficients R^2 for oxidation of Phenol at different initial concentration

Phenol concentration (mM)	k(obs) (min^{-1})	$t_{1/2}$(min)	R^2
2	0.96	6.93	0.98
4	0.98	6.89	0.99
5	0.98	6.97	0.99

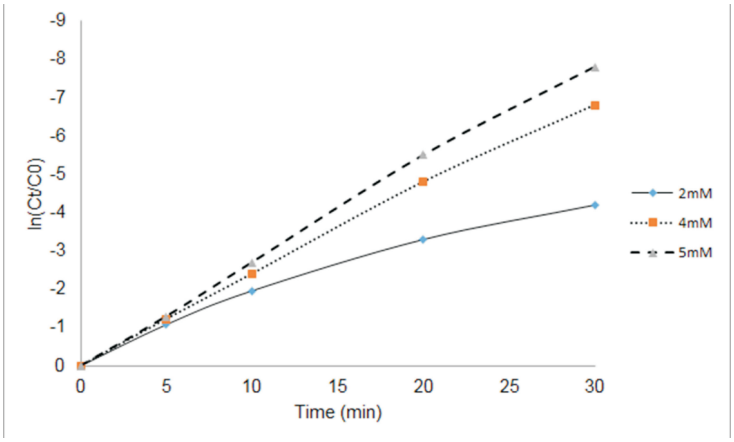

Figure-4: Pseudo First Order Relationship of Phenol Oxidation by Fenton Oxidation at Different Initial Concentration

linear regressions are performed to observe the effect of pH, H_2O_2 and $FeSO_4.7H_2O$ on percentage degeneration of phenol (Equation-3).

$$\text{Phenol Degeneration} = 39.164 - 9.511(\text{pH}) + 475.726(\text{H\_2 O\_(2)}) + 54650.073(\text{FeSO\_4.7H\_2 O}) \quad (3)$$

In above model, 39.164 is known as an intercept of the fitted regression model. The pH has negative relationship with phenol degeneration; the one unit increase in pH results 9.51 units decrease in phenol degeneration. H_2O_2 and $FeSO_4$ have highly positive relationship with phenol degeneration. The coefficient of determination of fitted regression model is 84.79%, which means 84.79 percent variation of the degeneration is explained by the pH, H_2O_2 and $FeSO_4$. More explicitly, it can be said that the results of the model are 84.79% reliable for further predictions. It is to be noted that the above model is valid only if the independent variables pH, H_2O_2 and $FeSO_4.7H_2O$ takes the values within 3, 7; 10, 100 mM; and 0.0, $1x10^{-4}$ mM, respectively. Analysis of variance test is performed to evaluate the reliability of fitted regression model. The results of ANOVA are presented in Table-2. It is observed (Table-2) that all p-values are less than 0.01; representing significant contribution of pH, H_2O_2 and $FeSO_4.7H_2O$ for predicting phenol oxidation.

4. CONCLUSIONS

Fenton oxidation of phenol in aqueous medium under pulsed mode of ultrasonic irradiation showed that 99.5% of phenol was degraded when experiments were conducted at 80 mM H_2O_2, $8.9x10^{-4}$ mM $FeSO_4.7H_2O$, pH of 3. Sonofenton oxidation is proved to be an effective tool as compared to simple Fenton for oxidation of phenol. Kinetic study shows that phenol oxidation followed pseudo first order reaction having specific rate constant k= 0.1 min^{-1} and half-life of 6.93 min. Finally, a latest version of R software was used to develop regression model by quantifying pH, concentration of hydrogen peroxide and concentration of ferrous sulphate. The regression model elucidated that pH increase has negative whereas increase of H_2O_2 and $FeSO_4.7H_2O$ has a positive impact on phenol oxidation.

ACKNOWLEDGEMENTS

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Table-2: Statistical Analysis of Phenol Oxidation at Different Response (pH, H_2O_2 and $FeSO_4.7H_2O$)

Response	Sum of square	Mean square	F-value	p-value
pH	1386.7	1386.7	21.647	8.41E-05
H_2O_2	1392.8	1392.8	21.742	8.41E-05
$FeSO_4$	3229.0	3229.0	50.406	1.54E-07

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HOW THE NEXT WAVE OF TECHNOLOGICAL INNOVATION WILL CHANGE THE NATURE OF WORK, EMPLOYMENT, EDUCATION AND TRAINING

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*Andrea Clayton****

ABSTRACT

Advances in science and engineering have a profoundly transformative effect on every aspect of our daily lives. Most of these are very positive, improving health, generating wealth, driving development and creating new opportunities. However, as a result of the current pace and breadth of technological development, disruptive effects could become more rapid and frequent. Artificial intelligence could displace most existing jobs, and is already driving a transformation of social and economic systems that is happening ten times faster and at 300 times the scale of the first Industrial Revolution. The challenge, therefore, is to develop the research, education and training programs needed to prepare an entire generation for new modes and models of work. If we do not find viable and economically attractive solutions, then the likely outcome is extreme polarization between a small global elite and an increasingly disadvantaged underclass, with a corresponding increase in the risk of civil unrest, crime and terrorism.

1. INTRODUCTION

Advances in science and engineering have a profoundly transformative effect on every aspect of our daily lives. All of us depend on modern agriculture, energy and water engineering, while medical science now allows us to control many infectious diseases that, in an earlier age, destroyed entire populations. However, many great challenges lie ahead. A combination of demographic growth, rapid development and rising consumption could result in global shortages of food, water and energy, as well as an extensive loss of biodiversity, and accelerate the rate of climate change .

This is a cause for action, not despair, because every major problem stimulates the search for new solutions. The pace of innovation, technological development and change continues to accelerate across a broad front, as a result of dramatic progress in fundamental science, engineering applications and new product development. This is particularly rapid in areas such as biological science, informatics and nanotechnology, where both the fundamental science and the engineering applications are evolving simultaneously, changing basic concepts and perceptions as to what is possible. For example, molecular engineering will enable the manufacture of new materials with previously impossible combinations of lightness, strength, flexibility and other properties, which could lead to applications such as energy-efficient and safe vehicles, space elevator cables, bridges that span unprecedented distances and clothing that incorporates communication and diagnostic electronics. In the biological sciences, there are lines of research that promise the new generations of genetically-specific pharmaceuticals, advanced biofuels, and genetically modified plants and animals that will be needed to support a far larger human population in the decades ahead.

These technological changes will also drive a process of social and economic transformation. As Schumpeter (1942) noted, every major innovation creates new opportunities, demands and markets, but simultaneously renders the old technologies obsolete and the associated skills redundant. So innovation continuously disrupts and restructures the competitive environment, and drives a process of creative destruction, destroying the firms that have lost their markets, which allows the capital and the workforce to be reallocated into the new economic activities. In some instances – such as the move from horse to motor-based transport-entire new industries are created and old ones destroyed. In those countries with a large and diverse economy, the gains are substantial, as resources are continuously reallocated into areas where they generate more value. In countries with a narrow economic base, however, the fortunes of the entire nation can rise or fall accordingly, because there is little capacity to absorb the displaced workforce. This is particularly obvious in nations that depend largely on a single export, such as oil, where a fall in the price can precipitate an economic recession.

As a result of the current pace and breadth of technological development, these disruptive effects could become more rapid and frequent. If, for example, it proves possible to use genetically-modified bacteria to manufacture long-chain hydrocarbons that can then be refined into fuel, this would be very advantageous for the oil-importing nations that could then start to manufacture their own fuel, but countries that currently depend on exports of conventional oil could see their economies shrink sharply. A transition to eco-composites (engineering components made from plant fibers and resins) to replace petrochemicals would hurt the economies of countries that currently export petrochemical feedstocks, but would create major new market

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opportunities for agriculture, especially in sub-tropical regions, which would stimulate investment and growth in countries like Brazil. Investments in large scale solar plant in North Africa could be used to supply European markets, which could make previously unproductive desert regions very profitable. As these examples suggest, every significant technological development of this kind can create both winners (the firms, countries and regions that are well-placed to supply the new markets) and losers (those that see their former markets and exports decline).

So it is clear that the future will be very different from today - hopefully for better, possibly for worse, but certainly different. This creates a profound challenge for many countries. Where is their place in the new world? Will they be able to supply the goods and services that will be required in future? Or are they currently over-reliant on industries that might become redundant?

2. THE IMPLICATIONS FOR NATIONAL DEVELOPMENT STRATEGIES

It is widely agreed that a critically important part of any strategy for national development in today's world is to strengthen scientific and technical capacity, to produce graduates that can create new enterprises and increase the productivity and competitiveness of businesses, and to develop a trained, skilled workforce, because it is believed that this combination will help to stimulate innovation, investment, economic growth and employment. It is, of course, impossible to anticipate all possible future outcomes that could result from the complex interaction of demographics, competition, geopolitics and technological innovation, so some investments will be more successful than others, but this does not invalidate the core strategy of human capital development.

There is now, however, a significant challenge to this approach, which is that the next wave of technological innovation could make many current forms of employment redundant. This would make it necessary to rethink the goals, nature and purpose of many current educational and training systems, as there is little point in training people to undertake tasks that can be done more efficiently and cheaply by artificial intelligence and automated systems.

3. THE IMPACT OF AUTOMATION

Automation has gradually replaced many tasks that were previously done manually. This has allowed the workforce in most countries to migrate from primary to secondary industries, and then into tertiary services. This has transformed labour markets. Until the early 20th Century, most of humanity worked in agriculture, mainly because the relatively low productivity at the time meant that most of the agricultural workforce were not generating large surpluses, and so could not support a large number of people in other sectors. A large modern economy such as the USA, however, has less than 0.5% of its workforce in agriculture. Mechanization has replaced labour, which has generated enormous agricultural surpluses, allowed almost the entire workforce to migrate from the land into other forms of employment, and, thereby, created a vast amount of additional wealth.

It is important to note that this process has, to date, been enormously positive, because the process of innovation and technological development has created far more jobs than it has destroyed. There is no fixed amount of labour in any economy, as people have always found new ways to add value, and create goods and services for which there is a demand.

What is changing, however, is the speed of change itself. The automation of primary industries (such as agriculture) happened over many generations, the automation of secondary industry happened within one or two generations, and neither process is yet complete. The difference now is that the next wave of automation could replace most existing jobs, and do so within just one or two decades. The McKinsey Global Institute estimates that artificial intelligence is now driving a transformation of social and economic systems that is "happening ten times faster and at 300 times the scale, or roughly 3,000 times the impact" of the first Industrial Revolution.

In previous waves of technological change, increasingly diverse jobs were created in new sectors of the economy at a pace that could absorb much of the labour that was being displaced. There are some indications that the next wave will be too swift to allow an easy transition for much of the current workforce. As many formerly middle-class jobs have become unnecessary in the post-industrial societies, many of the people that used to hold those jobs did not move into more highly skilled jobs, but shifted into lower-paid work, mainly because they did not have the training to make the transition to a job at the same rate of pay. This suggests that there is a rapid change happening in terms of the kind of skills that people need, and that the education system is lagging behind the trend and failing to give people the skills sets and adaptability

that are now required. Demand is growing for highly skilled, highly educated workers, but declining for those with low to moderate levels of education, which means that these people are more likely to be displaced downwards or out of the formal economy entirely . For many people, the future will involve doing work that is more interesting and fulfilling than today, using machines to enhance and extend their skills, but for those that are not well-placed to make this transition, the future may look bleak. For many societies, it may become necessary to develop new forms of economic activity with equally unprecedented speed – or else face the risk of rising unemployment, rapidly increasing inequality and potentially serious social dislocation and civil unrest. This problem is likely to be compounded by the fact that while many people expect that the future will involve far more automation than today, relatively few expect it to happen to their jobs. A report by the Pew Research Center (2016) found that most Americans expect significant levels of workforce and job automation to occur over the next 50 years, but that most of today's workers did not think that their own jobs or occupations would be affected; 36% of workers anticipated that their current jobs or occupations would 'definitely' exist in their current forms five decades from now, while another further 44% expected that their jobs would 'probably' exist in 50 years . This means that this group is unlikely to make the necessary investment in retraining.

4. SPEED OF CHANGE

It now appears possible that automation could now rapidly replace most remaining routine tasks while the next wave of development will see information technology systems replace many highly skilled processes, even in areas such as medicine, law and finance. This is being driven by the '4th Industrial Revolution', which involves the integration of previously separate fields such as artificial intelligence, robotics, nanotechnology, 3D printing, genetics and biotechnology. This is likely to introduce a new wave of radical innovations, and destroy 'old' jobs with unprecedented speed. Frey and Osborne (2013) suggested that almost half of the current jobs in the USA could now be automated. Additive manufacturing (with 3-D printers) could replace factories, construction workers and architects.

Online courses could allow universities to operate with far fewer teaching staff, while online services could allow governments to operate with a much smaller civil service. Many of the current generation of low-paid jobs could also be vulnerable; as the former CEO of McDonald's pointed out recently, it is now 'cheaper to buy a $35,000 robotic arm than it is to hire an employee who's inefficient making $15 an hour bagging French fries.' The cost savings will be dramatic. The Bank of America Merrill Lynch predicts that by 2025 the annual savings from the replacement of employees by artificial intelligence will reach US$9 trillion, with an additional cost reduction of US$8 trillion from efficiency gains in manufacturing and health care, and a further US$2 trillion in efficiency gains from the deployment of self-driving cars and drones .

5. THE REVOLUTION IN TRANSPORT

The transport sector provides a good example of the impact of future change. A number of firms are developing driverless vehicles, and a range of countries (including the UK and various states in the USA) have started the process of legalizing their use on the roads. This has revolutionary implications for road transport; it will make it much cheaper, safer and more reliable, mainly by replacing humans. At present, about 75% of the cost of shipping goods by road across the USA is the cost of the labour involved, so eliminating the workforce will reduce the cost by the same percentage. In addition, driverless trucks can work for 24 hours per day, while drivers in the USA are restricted by law from driving more than 11 hours per day (9 hours in the UK). This means that the shift to driverless trucks would double the capacity of the US road network while reducing the cost per load by 75%, giving an eight-fold improvement in the price-performance of ground transportation networks. Automated vehicles are also much more fuel-efficient (as they can be programmed to run at optimal cruising speed), and far safer (on average, over 33,000 people die in road accidents in the USA each year, mostly as a result of human error, so many of those lives could be saved). Similarly, substantial savings will be made in other regions, such as Europe, where over three-quarters of all shipped goods are transported by road.

Shipping represents a significant part of the cost of all consumer goods, so an eight-fold improvement in the price-performance of ground transportation means that consumers everywhere will see prices fall significantly and their standard of living rises commensurately. The impact on employment, however, will be equally dramatic. About 1.6 million people in the USA work as truck drivers, which is about 1% of the workforce, and most of them would then become redundant, along with many of the jobs in support activities such as local deliveries, gas

stations, diners and motels; a total of nearly 9 million people in the USA who would lose their current jobs .

6. THE TRANSITION FROM OWNERSHIP TO ACCESS

Another defining future trend is that the need to own a physical device to obtain a particular service will be removed by the servicisation of the economy. For example, Airbnb has become the world's largest hotel chain without ever owning a single hotel room. Similarly, many people no longer own their music recordings because they can now use services such as Spotify and YouTube to access whatever track they want to hear, whenever they want.

This model has already extended to mobility. One of the first working models, called Car2Go, was developed in the city of Ulm, Germany, in 2008 . Users were given mobility on demand, without the need for ownership, maintenance costs, insurance or any other asset management requirements. They can now take a car whenever they need one, use it for as long as they want, and leave it at a nearby drop-off point. In addition, the cars are fitted with diagnostic systems; this allows maintenance schedules, inventories of spare parts and so on to be optimized. This is far more efficient, much cheaper and more convenient than individual car ownership – and may eventually remove the need for most people to ever own a car. Similarly, Uber is rapidly destroying the business model for taxis. These effects will be compounded by the transition to driverless cars, which will eliminate the need for both public transport and private car ownership.

These examples illustrate several aspects of the transition away from the ownership of physical goods to access to services. It is clear that many consumers no longer require ownership if they want to enjoy a service, but the intensity of use is typically much higher, dramatically improving efficiency. At present, most cars are parked for 95% of the time , representing a very inefficient commitment of capital, but removal of the need for ownership could reverse that ratio.

These innovations will generate extraordinary efficiency gains, but will also make car salesmen, driving instructors, car insurance salesmen, car park attendants, traffic police and many other associated jobs unnecessary.

7. JOBS THAT MAY DISAPPEAR

There are a number of jobs that are now clearly vulnerable to automation. These include most office jobs, data handling, logistics, tax and auditing, secretarial and accounting positions, as data and text processing and accounting are increasingly being replaced by software, receptionists, cashiers, bank tellers, airline check-in staff and postal services, as most of these tasks can be replaced by electronic communications and self-service points, couriers, who can be replaced by better e-document security and secure electronic signatures, government bureaucrats, who can be replaced by better online systems and integrated databases (this is already happening in countries like Denmark and Estonia); paralegals, who can be replaced by semantic analysis software that can determine relevance and precedents; farmers, some of whom can be replaced by automated hydroponic systems and tissue-culture meat protein; security guards, some of whom can be replaced by inferential analysis software that can identify suspicious content or pattern of behaviour; and even many medical services, which can be replaced by expert diagnostic systems. Fighter pilots are being replaced by Unmanned Combat Aerial Vehicles (UCAVs), computer chip designers are being replaced by software, and many manufacturing operations (including construction) are likely to be replaced by 3-D printing. All jobs that depend on information asymmetries are vulnerable, as information asymmetries are disappearing in on-line markets. These include realtors, who can be replaced by searchable GIS systems that list titles and permit sales and secure transfers, brokers, who can be replaced by automated transactions and travel agents, who can be replaced by software that knows personal preferences and searches for best routes, dates or prices.

8. THE IMPACT IN DEVELOPING COUNTRIES

Developing countries too will be profoundly affected. For example, over half of all jobs in Angola, Mauritius, South Africa and Nigeria, up to 85% of all jobs in Ethiopia and almost 90% of the 400 million jobs in low-income countries could be now be automated. This means that the traditional path to growth (which involved moving workers from agriculture to more productive jobs in factories) may not be available to today's low-income countries. This means that they will have to find new development pathways.

9. ADAPTING TO CHANGE

It is clear that these trends will have a transformative effect on economic structures and on work and

employment. How can countries prepare for such profound change?

A new commitment to human capital development is likely to be part of the solution, as skilled jobs are less susceptible to automation, but this requires a coherent strategy for change. As noted earlier, there is no point in investing in skills in an area that is about to become redundant. In general, jobs that require originality, social and creative intelligence, perception of irregular spaces and manipulation are very difficult to automate and are, therefore, at low risk of replacement in the near future. These areas do not, however, provide the kind of mass employment opportunity that can create livelihoods for millions of people. Some countries are now considering whether a basic income scheme (a guaranteed income for all citizens) will be necessary to prepare for a world in which many conventional forms of employment will cease to exist, but this will be politically difficult unless it can either be restricted to citizens (Switzerland recently rejected a basic income scheme because of concerns that it would encourage immigration), or else is introduced universally, which would not be feasible for low-income countries.

The profound challenge facing the world, therefore, is to identify new growth areas and to develop the research, education and training programs needed to prepare an entire generation for new modes and models of work. If we do not find viable and economically attractive solutions, then the likely outcome is extreme polarization between a small global elite and an increasingly disadvantaged underclass, with a corresponding increase in the risk of civil unrest, crime and terrorism.

This suggests that the workforce will have to be far more mobile and flexible in future, and that it will be increasingly important to anticipate or respond positively to change. The challenges therefore include the following:

- How can people be prepared for jobs that may not exist yet?
- What will be the new industries and business opportunities?
- Which jobs could disappear?
- What jobs will be required in future?

10. THE ROLE OF EDUCATION AND TRAINING IN DEVELOPMENT

It is also essential to reconsider the role of educational and training institutions in national development; traditional 'supply-push' models of the role of educational systems in developing countries have largely ignored both the larger economic context of global change and the need to foster innovative capacity.

Educational and training systems have a crucially important role to play in supporting and enabling a transition to a skill-based economy. They cannot, however, drive this process. The distinction becomes clear when considering the failure of traditional strategies for education and training, which have tended to focus on increasing the supply of skilled and educated people into the workforce. There is little evidence, however, that the process of economic development can be directly supply-pushed by education and training. For example, an oversupply of over-qualified graduates in an economic recession can lead, instead, to a situation where many university graduates are unemployed or underemployed, and consequently disaffected, or emigrate in search of better opportunities overseas .

The evidence rather suggests that education is demand-pulled by economic development. As economies strengthen and diversify, they assume the inverted pyramid shape of a mature economy (in which tertiary service sectors increasingly dominate secondary processing and manufacturing sectors, which in turn increasingly dominate primary mining and agricultural sectors). As this happens, the demand for a widening range of increasingly diverse, specialist and sophisticated skills expands, which thus expands the range of opportunities and demands for educational courses. The development of India's ICT industry, for example, was made possible by the availability of a large number of underemployed mathematics graduates, but these graduates would probably have remained underemployed had it not been for the Indian Diaspora in California, who provided the link to markets, ideas and business opportunities that demand-pulled subsequent developments, as well as the investment capital and technology-transfer that triggered and accelerated the subsequent rapid growth.

This raises a number of fundamental issues. For example:

- Can the educational and training systems in developing countries make a stronger contribution to economic development? Should available resources be focused on areas where there is potential demand-pull? Given the long lead-time

required to develop new courses and produce the first graduates, is it possible to identify these areas in advance? Which areas will generate the future employment opportunities, and what are the associated training needs?
- Which elements of funding for research, education and training should have priority if demand-pulled training is to succeed? What are the implications for resource allocation? Where do schools, colleges, universities and adult training agencies fit into this process? Where are the key entry points for effective intervention?
- Is it possible to support the development of increasingly knowledge-based economic activities by encouraging entrepreneurship in knowledge and service-based economic activity – particularly in countries and sectors with a relatively thin skill base in those areas?
- What are the implications of rapid technological change for generating new employment opportunities - and destroying redundant business activities?

11. ANTICIPATING THE FUTURE

The further we look into the future, the less we know for certain about it. This means that we have more scope to shape development trajectories towards our preferred outcomes. It also means that our forecasts are more likely to be wrong. However, the real choice for most countries is to either engage constructively with the global trends, or to be driven by decisions made by others, with all the negative implications that will have for the domestic economy and the local skill-base. In effect, this is a choice between taking part in the process of change, or else becoming increasingly powerless. The critical success factors are likely to include:

- Understanding the possible future pathways;
- Developing a strategy for the transition;
- Developing the skills that will be needed in the years ahead, and disseminating these skills into the workforce.

CONCLUSION

The next wave of technological innovation and change is likely to have a particularly rapid and extensive effect on economic structures and on the nature of work and employment. Many new jobs will undoubtedly be created, but a far larger number of current forms of employment are likely to become displaced, at least in the short term. This could create enormous social problems unless there are large-scale programs to adapt educational systems to help people prepare for profound change. This is likely to involve a focus on jobs that require originality, social and creative intelligence, as these are difficult to automate and are at low risk of replacement in the near future, but these activities are unlikely to provide mass employment opportunities. The profound challenge facing the world, therefore, is to identify new growth areas and to develop the associated research, education and training programs needed to prepare an entire generation for new modes and models of work.

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DEVELOPMENT OF PRODUCTION TECHNOLOGIES FOR WARM MIX ASPHALT ADDITIVES

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ABSTRACT

In last decade, warm mix asphalt (WMA) technology has been used as an alternative to hot mix asphalt (HMA) that reduces the temperature during production and placement, and minimizes greenhouse gases while maintaining the properties of HMA. In Turkey, between 2012-2015, a project named "Development of Production Technologies for Warm Mix Asphalt Additives" was implemented by the Institute of Chemical Technology of TUBITAK Marmara Research Center (MAM), and R&D Department, General Directorate of Highways, Republic of Turkey. The objective was to develop and produce zeolitic base WMA additive. Additives were synthesized in a laboratory, a semi pilot plant and a pilot plant. Pilot asphalt laying was applied in Ankara for 400 meters by produced and commercial zeolitic base additive. The results showed that the performance of the additive produced in TUBITAK MAM had better wheel tracking results and higher TSR (Tensile strength ratio) values than commercial additives.

Keywords: *warm mix asphalt, warm mix asphalt additives, zeolite, warm mix asphalt performance tests.*

1. INTRODUCTION

Hot mix asphalt (HMA) is used as the primary paving material in the world, which consists of aggregate and asphalt binder which are heated and mixed together. The primary sources of emissions in an asphalt plant are the mixers, dryers and hot bins, which emit particulate matter, such as dust, smoke, exhaust vapor and other gaseous pollutants. Some other sources of emissions found at an asphalt plant are the storage silos, truck loading operations, binder storage tanks, stockpiles, etc. In order to reduce the emissions from asphalt plants, the asphalt industry is constantly trying to reduce mixing and compaction temperatures of mixes, without significantly affecting their properties. The asphalt industry has been experimenting with warm and cold asphalt mixtures for decades to reduce energy requirements and for environmental benefits [Sutton, 2002].

Warm mix asphalt (WMA) is an asphalt mixture which is combined at temperatures lower than conventional hot mix asphalt. Typically, mixing temperatures of warm mix asphalt range from 100°C to 140°C compared to mixing temperatures of 150°C to 180°C for hot mix asphalt. Thus, warm mix asphalt has been gaining an increasing popularity in recent years. Rising energy prices, global warming and more stringent environmental regulations have resulted in an interest in warm mix asphalt technologies as a means to decreasing energy consumption and emissions associated with conventional hot mix asphalt production [Jones, 2004].

European countries are already using warm asphalt technologies that allow reductions in mixing and compaction temperatures of about 20°C to 55°C. The asphalt industry has developed several methods to reduce mixing and lay-down temperatures of asphalt mixtures. In principle, there are three major methods for the preparation of asphalt mixtures at low temperatures. These methods are foaming, organic additives and chemical additives. Foaming is done either by adding water directly or adding water bearing additives that are generally natural or synthetic zeolites into the asphalt mixture [Koenders, et al., 2000].

Warm mix asphalt technology has many advantages as compared to hot mix asphalt. It reduces emissions, provides better working conditions because of the absence of harmful gases and lower energy consumption in mix production. Since, the compaction and mixing temperature is lower with WMA technology, it provides quicker turnover to traffic, longer hauling distances and extended paving period.

2. WARM MIX ASPHALT

Bitumen is used as a binder in asphalt overlaying. Bitumenous binders are in solid form under normal weather conditions and its viscosity should be reduced for fluidizing and its workability should be increased to mix with agregates for producing asphalt concrete and to fill the aggregate voids for a good adhesion. This process is accomplished by heating the bitumenous binders to high temperatures in asphalt plants for hot mix asphalt concrete production.

The production of hot mix asphalt is responsible for a large consumption due to the heating of its components (aggregates and binder). This energy is spent on the burning of fossil-fuels and the consequent greenhouse gas emissions. The implementation of the Kyoto Protocol in 2005, which has been extended until 2020, aims to have the signatory countries undertaking measures to reduce

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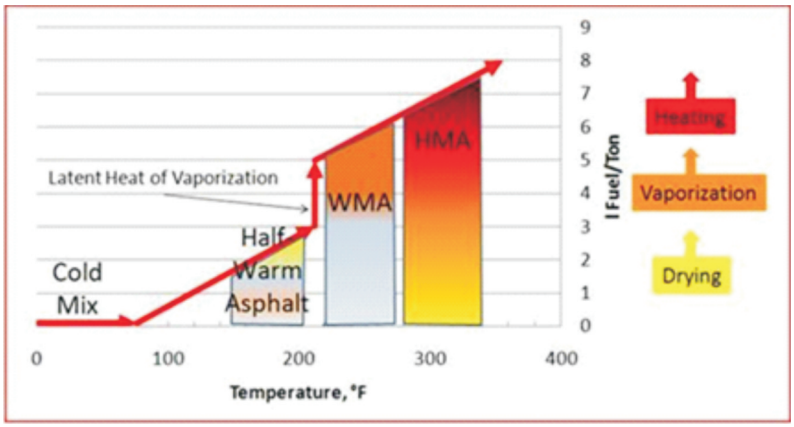

Figure-1: Classification by Temperature Range, Temperatures and Fuel Usage

those atmospheric emissions. Thus, new manufacturing techniques have been developed, and the decrease of temperature plays an important role in this technique (Figure-1).

WMA is a technology used in road construction and has the potential of improving energy efficiency by reducing the temperature at which the asphalt pavement material is mixed and placed on the road. WMA can usually lower asphalt-mixing temperatures by 15°C to 30°C compared to conventional hot mix asphalt (HMA). WMA can be used in all bitumenous mixtures including dense graded asphalt, stone mastic asphalt, porous asphalt and mastic asphalt.

The data gathered with the assistance of the members of the European Asphalt Pavement Association have been shown in Table-1 and Table-2.

The most important benefit of using WMA is the significant lower bitumen fume level during paving operations compared to HMA. Also, there are many advantages that are classified into three different categories shown in Table-3.

3. BENEFITS OF WARM MIX ASPHALT TECHNOLOGY

3.1 Reduced Fuel Usage

Since the main advantage of warm mix is the reduction of mixing and compaction temperatures, compared to HMA there is significant reduction in the usage of fuels. Before mixing the aggreagtes with asphalt, aggregates are heated to get rid of the moisture. The additives reduce the viscosity at lower temperatures making it easy to mix asphalt with the aggregate at a lower temperature. Thus, with the use of additives, it is possible to, lower the mixing and compaction temperature; therefore resulting in savings of up to 35% [Sampath, 2010].

3.2 Better Workability and Compaction

WMA allows better workability at lower temperatures due to inclusion of additives. Better workability would result in better compaction of the pavement since it would take fewer roller passes to obtain the desired air voids for the pavement. Figure-2 shows better working

Table-1: Total Production of Hot and Warm Mix Asphalt in 2008-2014 (in Million Tonnes) [EAPA, 2014]

Country	2008	2009	2010	2011	2012	2013	2014
EU-28	300	291.6	262.6	268.5	226.7	219.7	219.4
Europe	338	326.9	309.3	324.3	276.4	277.3	265.4
Australia	9.5	9.5*	7.5		8.8		9.1
New Zealand					1	1	
Japan	49.6	49.6	44.7	45.6	47.3	49.9	45
(Ontario) Canada	13.2*	13.2*	14	13.5	13		13.8
USA	440	324	326	332	326.9	318.1	319
South Africa				5.7	5.7	5.5	5.4
South Korea		35.6	20.7		23.2	26.2	
Note: **estimated values, blank: no data.*							

Table-2: Production of Warm Mix Asphalt in 2013 and 2014 [EAPA, 2014]

Country	2013 (million tonnes)	2014 (million tonnes)
Austria	0.000	0.000
Belgium	No data	No data
Croatia	0.000	0.040
Czech Republic	0.030	0.001
Denmark	0.120	0.200
Finland	0.000	0.120
France	3550	4023
Germany	No data	No data
Great Britain	<1.000	<1.000
Hungary	0.020	0.038
Luxemburg	0.000	0.007
Netherlands	0.060	0.133
Norway	0.380	0.540
Slovenia	0.000	0.000
Spain	0.086	0.140
Sweden	0.500	0.700
Switzerland	0.870	0.388
Turkey	0.000	0.000
USA	69000	103000
Japan	0.152	0.231
Ontario-Canada	No Data	0.750
South Africa	0.150	0.150

Table-3: Potential Benefits of WMA [Sampath, 2010]

Potential Benefit	Economic	Operational	Environmental
Reduced fuel use	X		X
Late season (cool weather) paving		X	
Better workability and compaction	X	X	
Reduced plant emissions of greenhouse gases			X
Increased usage of RAP	X		
Improved working conditions for plant and paving crew		X	

conditions with less fume in warm mix asphalt pavement [Sampath, 2013].

3.3 Reduced Emissions of Greenhouse Gases

Asphalt mixing is a more energy intensive process as compared to other industrial activities. The energy consumed during the mixing process was as much as 60 percent of the total energy required for the construction and maintenance of a given road over a typical service life of 30 years [Sampath, 2013]. The use of WMA techniques allow for reduction in required mixing energy and subsequently allow substantial savings in energy costs. According to previous

Figure-2: Warm and Hot Mix Asphalt Pavement [Asphalt, 2013]

Table-4: Reduction in Emission of Greenhouse Gases [Sampath, 2010]

Emission	Reduction in measured Emission-WMA (compared to HMA)
CO_2	15-40 %
SO_2	18-35 %
NO_x	18-70 %
CO	10-30 %
Dust	25-55 %

studies, this correlates to burner fuel savings with WMA processes ranging from 20 to 35 percent. A lower temperature used during the production accounted for reduction in electrical usage to mix the material, as well as to transport the material through the plant. With the use of WMA technology, consumption of fuel and emission of Green House Gases (GHGs), such CO_2, SO_2 and NO_2, decreases [You, 2011]. The reduction in the mixing temperature causes a visible reduction in the smoke and odor, and may thus result in improved working conditions. Table-4 shows the reduction of emissions by using WMA.

3.4 Increased Usage of RAP

Reclaimed Asphalt Pavement (RAP) is the term given to asphalt that has been removed and/or reprocessed and can be used as aggregates for laying roads. The usage of RAP in HMA has been limited by many highway agencies due to the concern that the materials might get aged at high temperatures and would potentially lead to early cracking of the roads. The mixing temperature in WMA is significantly lower and can thus facilitate the use of RAP for construction.

There are three major methods for preparation of warm asphalt mixtures: foaming, organic additives and chemical additives. Two different foaming tecniques are applied to reduce the viscosity of bitumen, injection of water and adding minerals. The foaming process by injection of water generally produces tiny steam bubbles inside the asphalt binder, which causes a volume increase, leading to increased wettability of the binder and lower high shear viscosities [EAPA, 2014a].

The method with water bearing additives is based on the release of chemically bound water from the additives into the binder during the mixing process. Release of this water leads to a finely dispersed steam when it comes in contact with the heated aggregate and binder. The fine steam bubbles lead to micropores that improve the compaction properties of the binders. This indirect foaming technique uses hydrophilic minerals from the zeolite family [Sampath, 2010].

Water containing technologies use synthetic zeolite to produce the foaming process. The product is composed of aluminosilicates of alkali metals, and has been hydro-thermally crystallized. The zeolite has approximately 20% water, which is released from the structure with temperature rise [Rubio, 2012].

The second method is based on adding special organic additives to the binder to reduce its viscosity. Such types of additives typically consist of paraffinic hydrocarbons. Paraffins are generally soluble in the asphalt binder in the temperature range of 80-120°C

[Hill, 2011]. The process show a decrease of viscosity above the melting point of the wax, making it possible to produce aphalt concrete mixes at lower temperatures. After crystallisation, they tend to increase the stiffness of the binder as well as the asphalt's resistance against deformation. The type of wax must be selected carefully so that the melting point of the wax is higher than expected in service temperature and to minimize embrittlement of the asphalt at low temperatures [Zaumanis, 2010; Silva, 2010].

The chemical additives usually include anti-stripping agents that are designed to enhance coating, adhesion and workability of asphalt mixture. They do not change the bitumen viscosity. They regulate and reduce the frictional forces at the microscobic interface of the aggregates and the bitumen [EAPA, 2014a].

4. DEVELOPMENT OF PRODUCTION TECHNOLOGIES FOR WARM MIX ASPHALT ADDITIVES PROJECT

A project titled "Development of Production Technologies for Warm Mix Asphalt Additives" was implemented between 2012-2015 by TUBITAK MAM, Institute of Chemical Technology and R&D Department of General Directorate of Highways (KGM), Turkey.

Its scope, components and methodology is given as follows:

4.1 Scope

- Development of production technologies for warm mix asphalt additives,
- Production of WMA additives to use in highways,
- Development of design mixtures by using the produced WMA additives,
- Examination of the potential usage of natural resources (zeolite, bentonite) as WMA additive,
- Determination of performances of design mixtures produced by WMA additives with advanced methods,
- Application and performance determination of asphalt design mixture prepared by WMA additives produced in pilot scale,
- Development of application technologies for WMA,
- Preparation of technology knowledge package of product and production,
- Extension (commercialization) of technology knowledge package through legal arrangements (technical specification/circular order).

4.2 Project Components

- Project management,
- Literature research,
- Characterization of commercial products, choosing and making the performance tests, Using natural mineral resources as additive in WMA,
- Using synthetic zeolite as additive in WMA,
- Using parafinic wax as additive in WMA,
- Production of developed WMA additives in pilot plant,
- Application of produced additives in pilot areas and performance testing,
- Report preparation, workshop organization and preparation of technology knowledge package of product and production.

Chemical engineering and technology, chemical process engineering, civil engineering and technology, mining engineering and technology, chemical process equipments and materials, economical and technological analysis, environmental engineering and technology, energy and environmental politics areas were used for the implementation of work components.

Procurement of bitumenous binders and aggregates, determination of mixture type, making design mixture by using developed WMA additives, performance experiments, asphalt laying to pilot areas by using WMA additives produced in MRC were performed by specialized technical experts of General Directorate of Highways in bitumenous mixtures laboratories.

4.3 Methodology

Pre-studies: detailed literature research, procurement of raw materials and commercial products, test/analysis and characterization, procurement of device and equipments;
Laboratory studies: establishing systems, experimental studies, concept and design verification, product performance tests;
Pilot plant modification: process and auxiliary equipment, technical specification and procurements, pilot plant infrastructure needs, modification studies;
Pilot plant studies: experimental studies, process optimization, design verification, determination of progressive areas, production, product performance tests;

Pilot asphalt laying: WMA application technology, preparation of mixture design;
Preparation of technology knowledge package for product and production: process design, design drawings, P&ID schemes, 3D installation and placement drawings, technical and economical feasibility, plant manual.

5. RESULTS

Highways are important part of any transportation systems, and cater to commuting of 95% of passengers and 92% of cargo transportation. Asphalt surface course is made of some specialized pavements to increase the durability against traffic, environmental and climate conditions for safe and comfortable roads. Hot Mix Asphalt (HMA) and Surface Treatment (ST) are used in Turkey for asphalt pavement. As of 2015, General Directorate of Highways have 2,155 km motorways, 31,280 km state highway and 32,734 km provincial roads of total 65,909 km network. All the highways include motorways; 27% are HMA, 73% are ST and 34% are dual carriageway. HMA used in 2013 was 46.2 million tons (motorways, highway and provincial roads). During the next decade or so, Turkey is targeted to extend the total dual carriageway length, and asphalt concrete is targeted to be applied to all highways.

The WMA Addtives Project of TUBITAK MAM was aimed to develop and produce zeolite base WMA additive.

First, experiments were performed at laboratory scale for optimizing the production conditions of the additives. Additives were synthesized in 3 liter reactors and some detailed optimizations were made. After that step in a 50 litres reactor, semi pilot productions were conducted to see the difficulties that can be encountered in pilot scale production and the designs and modifications of the pilot plant were made

Figure-3: Pilot Plant at ICT Institute, TUBITAK MAM, Turkey

with the experience gained. In the pilot plant (Figure-3), 4 tons of the additive were sythesized and 3 kg packages were prepared to be used in asphalt plant.

In June 2015, pilot asphalt laying by using WMA additives was performed at Ankara Highway, Karapürçek intersection region (Figure-4). Pilot asphalt laying consists of 800 m, in which 400 m is applied with additives produced in TUBITAK MAM and 400 m is applied with a commercial zeolitic base additive. Also, hot mix asphalt without additive was layed to compare with the ones with additives layed at lower temperatures.

The rutting performance of three asphalt core specimens were measured by the wheel-tracking test. This test measures the rut depth produced by the repeated rolling of a loaded wheel for 20,000 loading

Figure-4: Pilot Asphalt Laying at Ankara Highway, Karapürçek Intersection Region

cycles. The results shows that TUBITAK MAM WMA additive performed the best wheel tracking results, whereas the commercial one had the highest rut depth.

The TSR (Tensile strength ratio) testing was used to evaluate the moisture susceptibility of the asphalt mixture. The moisture susceptibility was evaluated by comparing the tensile strength of asphalt mixtures in the dry and wet conditions. From the results, it was found that all the specimens made passed the minimum TSR value required by the General Directorate of Highways Technical specifications (TSR=0.80). In addition, the domestic WMA samples exhibited higher TSR value compared to commercial product.

According to unit weight, compaction percentage and air void of core speciments, WMA compressed better. Air voids are less and unit weights are bigger when compared to HMA. The field performance evaluations are more realistic as they simulate the real application. The results show that the performance of the additive produced in TUBITAK MAM has more dominant features than commercial additive.

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CHITOSAN: A NATURAL POLYMER WITH POTENTIAL INDUSTRIAL APPLICATIONS

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ABSTRACT

Chitosans are a family of natural polymers, composed by N-acetylglucosamine and glucosamine, commercially isolated from by-products of the fishing industry and aquaculture.

Chitosans have been promising biopolymers for almost fifty years and their use has been proposed in several fields, such as medicine, food industry, agriculture, cosmetics, biotechnology and so on. Unfortunately, the launch of chitosan-based products into the market has been irregular. Chitosan properties are strongly related to the polymer's physico-chemical characteristics and the first chitosan generation was unable to fulfill the requirements of most industrial applications since chitosan bioactivities claimed in the scientific literature were not reproducible.

The first generation of chitosans was poorly characterized and was followed up with a second generation of chitosans with well-defined characteristics. These samples allow producing reproducible chitosan-based products but are not suitable for very specific applications in biomedicine or pharmacology. Therefore, a third chitosan generation with defined monomer distribution, low polydispersity and clearly defined activities will open the door of new markets to these polymers.

Keywords: *Physico-chemical properties; biorenewable polymers; chitin, chitosan; oligomers*

1. INTRODUCTION

The manufacture of crustaceans from the fish industry and aquaculture produce tons of solid residues mainly composed of crustacean shells. This waste is a major source of surface pollution in coastal areas. The Food and Agriculture Organization (FAO) has estimated that the worldwide amount of crustaceans captured in 2014 in inland waters was around 530000 tons in marine fishing areas.

This implies that tons of crustacean waste (shells) is produced every year and that this huge volume of material needs to be properly managed. Each country has its own legislation regarding crustacean shells disposal but, in general, the tendency is a more restrictive legislation that increases the cost of waste management.

Traditionally, crustacean shells management includes the waste disposal in the ocean or landfills, their use as fertilizers after composting or their use as flour to feed animals in small amounts due to their high composition in inorganic materials. All these strategies have low or no added value. On the contrary, the isolation of the crustacean shells valuable components (chitin, pigments and calcium) reduces the amount of waste generated with a positive economic impact.

The proportion of inorganic salts (30-50%), proteins (30-40%) and pigments that can be found associated with chitin (20-30%) depends on several factors, such as the type of crustacean, the body part under consideration (head, torax, claws etc.), the molt stage, the season of harvesting and the location and environmental conditions (Naczk, et al., 1981; Yanar and Celik, 2005).

Chitosan can be easily produced from chitin after a multi-step process, in which the shells are demineralized and deproteinized to isolate chitin. When necessary, an extra step can be included to remove residual pigments depending on the final application. Chitin pigments are mainly astaxanthin and carotenoids that can be of interest for the food industry (for instance, as food coloring agents) and, therefore methods to pigment extraction has been specifically developed. Recently, an extensive review of chitin and chitosan isolation methods has been published (Younes and Rinaudo, 2015). During demineralization, inorganic salts (mainly $CaCO_3$ and phosphates) can be chemically removed by using strong basic media. Several conditions have been reported in the literature, none of them being able to avoid effects on the molecular weight and deacetylation degree of the polymers (Aranaz, et al., 2009). During the deproteinization step, proteins can be chemically removed using acid media or the process can be enzymatically carried out using proteolytic enzymes (tripsine, pepsine, papaine, etc). Complete deproteinization is very difficult due to the strong interactions among chitin and proteins. The chemical methods are more effective to remove the proteins than the enzymatic ones and, therefore, when human uses (food, biomedicine, pharmacy) are under consideration an extra chemical step with a sodium hydroxide solution (lower concentration and times that in a typical chemical process) is included (Aranaz, et al., 2014). The complete removal of proteins is necessary for human intended applications since a

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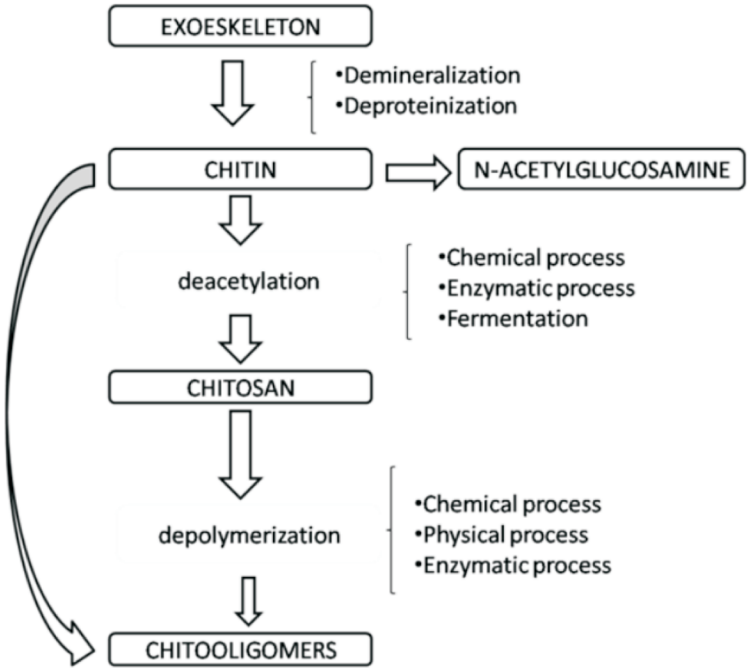

Figure-1: Production of Chitin, Chitosan and Chitooligomers

percentage of the human population is allergic to the protein components of the shellfish. The potential allergenic effect of chitosan is a controversial issue, eventhough some reports indicate the safety of chitosan (Muzarelli, 2010; Waibel, et al., 2011).

Chitin can also be isolated from microbial fermentation; in this case, both demineralization and deproteinization occur in one step. Although the biological methods (enzymatic or fermentation) produce chitin with a more preserved structure and have environmental advantages when compared with the chemical methods, these processes produce chitin at a higher cost and lower purity than the chemical ones (Kim and Park, 2015). It is worth mentioning that at this moment no standardized method to chitin isolation has been determined. In particular, further development is needed to find a cost-effective process that allows us to produce preserved chitin (samples with high molecular weight and deacetylation degree) having high purity.

Once chitin is produced, it can be submitted to a deacetylation process to obtain chitosan by alkali deacetylation. However, by this method, a partial degradation of the polymer occurs. The use of chitin deacetylases permits the production of well-defined chitosan samples avoiding polymer degradation. From chitin and chitosan, it is possible to produce oligomers and monomers (N-acetylglucosamine and glucosamine) by chemical, enzymatic or physical depolymerization (Harish Prashanth and Tharanathan, 2007; Kazami, et al., 2015; Kim and Rajapakse, 2005; Zou, et al., 2016). Depending on the composition of the polymers (chitin or chitosan with variable deacetylation degree) different oligosaccharides are produced. Homo-chitooligosaccharides are defined as low molecular weight polymers of variable length only composed by N-acetylglucosamine or glucosamine residues. Hetero-oligosaccharides are defined as copolymers of variable lengths composed of both types of monomeric units. Hetero-oligosaccharides differ in the degree of polymerization (DP), the degree of acetylation (DA) as well as in the location of monomers along the oligomer chain. The solubility in water of hetero-oligosaccharides depends on their DP, being soluble when the value is equal or minor to 10. The solubility of samples with higher DP depends on DA and pH of the solution. The interest of chitin and chitosan oligomers is due to their lower viscosity than the high molecular weight polymers, good solubility in aqueous media (in particular in biological environments), biocompatibility and their ability to penetrate biological membranes resulting in a high degree of adsorption. A general overview of the chitin, chitosan and oligomers isolation processes is shown in Figure-1.

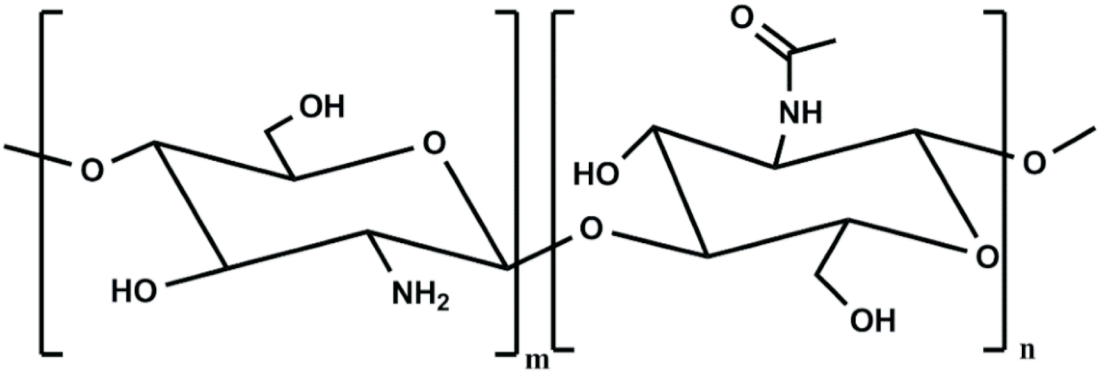

Figure-2: Chemical structure of Chitosan

2. TECHNOLOGICAL AND BIOLOGICAL PROPERTIES OF CHITOSAN

Chitosan is a biodegradable and biocompatible copolymer composed of randomly distributed monomers of β-(1→4)-N-acetyl-D-glucosamine β-(1→4)-D-glucosamine (Figure-2). The degree of acetylation (DA) of chitosan is defined by the molar fraction of N-acetylated units or as a percentage of acetylation (DA%).

As seen in Figure-2, chitosan contains primary amino groups, and primary and secondary hydroxyl groups on its structure. Chitosan is a polycation whose charge density depends on the degree of acetylation (amount of protonable glucosamine units along the polymer chain) and pH. Chitosan is not soluble in water but it can dissolve in diluted aqueous acidic solvents due to the protonation of the primary amine groups. Even highly deacetylated chitosan tends to form aggregates in acid aqueous solution due to strong interactions among polymeric chains. This hydrophobic behavior is based on the presence of both the main polysaccharide backbone and the N-acetyl groups of the N-acetylglucosamine units.

This chemical structure confers chitosan very interesting technological properties that are of great interest in several fields (Table-1). For instance, chitosan is able to produce and stabilize w/o/w emulsions without the addition of any surfactant due to the presence of N-acetylglucosamine residues that stabilize the water droplets inside the oil drops, while the glucosamine residues stabilize the oil drops in the multiple emulsion formed (Schultz, et al., 1998). Both molecular weight and deacetylation degree play a fundamental role in this process (Klinkerson, 2013). These properties are very valuable in the food industry where chitosan has been used as additive.

Chitosan has the ability to adsorb different types of molecules, such as dyes, metals and organic compounds among others. Chitosan is also involved in the coagulation-floculation process of different types of compounds. Interestingly, it seems that the accessibility of the primary amino groups is more relevant than chitosan deacetylation degree and, therefore the process is controlled by chitosan crystallinity (Guibal, et al., 2006). Due to this property chitosan has been used in waste water treatment and in the food industry for clarifying wines or juices (Li, et al., 2014; Wei, et al., 2013). The particular hydrophilic-hydrophobic balance in chitosan is related to its ability to stabilize carbon nanotubes suspensions in acid aqueous environments. The production of macroporous biocompatible carbon-chitosan nanocomposites has been reported with potential application as 3D electrodes in fuel cells and in tissue engineering (Aranaz, et al., 2014). The versatility of chitosan to produce films, scaffolds, fibers as well as micro and nanospheres is also very remarkable. Chitosan produces films by simple solvent casting methodology, scaffolds are easily produced by simple lyophilization process and micro and nano spheres are produced by several methodologies involving the use of multivalent anions, such as tripolyphosphate (Aranaz, et al., 2014; Aranaz, et al., 2016; Bugnicourt and Ladavière, 2016; Calderon, et al., 2013; Divya, et al., 2014). By interaction with polyanions, it is possible to produce chitosan-based polyelectrolyte complexes capsules or hydrogels (Luo and Wang, 2014). The production of chitosan fibers by electrospinning is not trivial. Chitosan has a limited solubility and chitosan solutions have large surface tension. That is why a polymeric mixture of chitosan along with other polymers is often used (Geng, Kwon and Jang, 2005).

Apart from these technological properties, some specific chitins and chitosans display biological

activities that are strongly correlated with the polymer physico-chemical characteristics; mainly the molecular weight, the degree of acetylation and the monomer distribution along the polymer chain (Table-1).

Chitosan has antimicrobial and antifungal activities. These activities are of great interest in the food industry and cosmetics as preservatives and in the agriculture field in order to control post-harvest diseases (Acosta, et al., 2015; Fernández-Sáinz, et al., 2013; Palou, et al., 2016; Romanazzi, et al., 2017; Ruocco, Costantini and Guariniello, 2016). In the textile industry, chitosan is a valuable material not only due to its antimicrobial properties but also due to its anti-shrinking properties (Yang, Wang and Huang, 2010; Zhang, Chen and Ji, 2003). Chitosan exhibits excellent mucoadhesive performance and it has been described as a potent adsorption enhancer that increases the absorption of poorly permeable drugs such as peptides and protein drugs (Caramella, et al., 2010). The mucoadhesive behavior has been related

Table-1: Main Technological and Biological Applications of Chitin and Chitosan and Fields of Use

Field of Use	Technological Application	Biological Application
Biomedicine Pharmacy	Fiber formation (electrospinning) Film production Polyelectrolyte complex formation with polianions Stabilizer of carbon entities Gelification in the presence of multivalent ions Ability to produce polymeric micro and nano spheres Polyelectrolyte complex formation with polianions (alginates, chondroitin sulfate, heparin and so on)	Antimicrobial Antifungal Mucoadhesive Hemostatic Mucoadhesive Anticholesterolemic Antioxidant Neuroprotective Antitumoral Anti-inflammatory Anti-diabetic Anti-HIV Adsorption enhancer
Food industry and nutraceuticals	Emulsifying activity Emulsion stabilizer Film production Flocculant Gelification in the presence of multivalent ions	Antimicrobial Antifungal Anticholesterolemic Antioxidant Neuroprotective
Cosmetics and Toiletries	Emulsifying activity Emulsion stabilizer Film production Ability to produce polymeric micro and nano spheres	Antimicrobial Antifungal
Biotechnology	Gelification in the presence of multivalent ions Ability to produce polymeric micro and nano spheres	
Textile industry	Fiber formation (electrospinning)	Antimicrobial Antifungal
Biocatalysis	Polyelectrolyte complex formation with polianions Ability to produce polymeric micro and nano spheres	
Waste water treatment	Flocculant	
Agriculture	Polyelectrolyte complex formation with polianions Ability to produce polymeric micro and nano spheres	Antimicrobial Antifungal

to its ability to interact with mucin due to its positive charge. The extent of this union depends on the amount of sialic acid present in the mucin and on the Mw and DD of chitosan (Aranaz, et al., 2009). Other authors have proposed a more complex behavior and suggested that hydrogen bonding and hydrophobic effects may also play a certain role. These properties have been widely exploited to produce pharmaceutical formulation for controlled drug delivery through different administration routes such as oral, ocular, nasal, vaginal and so on (Khutoryanskiy, 2011).

Chitosan has shown a significant scavenging capacity against different radical species, this antioxidant activity is very useful in the food industry to avoid the oxidation of highly unsaturated food lipids that cause off-favors and rancidity. Moreover, several diseases, such as cancer, Parkinson's disease, cardiovascular disease, premature aging rheumatoid arthritis, and inflammation among others have been related to oxidative processes. Chitosan has been proposed as an ingredient for production of nutraceuticals, which may prevent age-related and diet-related diseases (Hamed, et al., 2016). The neuroprotective effect of chitosan is not only due to its antioxidant activity and other effects, such as suppression of β-amyloid formation, acetylcholinesterase inhibitory activity (both related to Alzheimer's disease) and anti-neuroinflammatory effect has been described (Pangestuti and Kim, 2016).

A reduction of cholesterol after oral intake has been observed without reducing the serum iron and hemoglobin (Muzarelli, 1996). Other less frequent explored biological properties of these polymers are their analgesic effect, anti-HIV activity and antidiabetic activity (Gogineni, et al., 2015; Ju, et al., 2010; Li, et al., 2016; Okamoto, et al., 2002).

As previously mentioned, the first generation of chitin and chitosan were based on polymeric mixtures poorly characterized with a variable purity degree. Therefore, the composition of the mixtures was not reproducible. These samples are appropriated for technical applications such as floculant or adsorbent in waste water treatment, fungicidal in agriculture, clarifying in the food industry and so on. All these applications have in common that the physico-chemical properties of the polymers have a low impact on the behavior of the polymer. This first generation of chitosan is still dominating the current market; however, it is not appropriate for applications where purity and controlled composition are required.

Therefore, a second chitosan generation emerged

Table-2: Comparison Between Chitosan Generations and their Main Uses

Chitosan generation	Advantages	Disadvantages	Main Uses
First	- Large amounts in the market - Cheap	- Poor characterization - No reproducibility between batches - May contain pollutants	- Waste water treatment - Technological applications
Second	- Better Sample characterization - Higher Purity - Regulatory perspectives	- No reproducibility between batches	- Agriculture - Cosmetics - Food - Nutraceuticals
Third	- Control on sample characteristics - Physico-chemical characterization - High reproducibility of batches - Traceability - High Purity - Regulatory perspectives	- Limited amount in the market - High cost	- Agriculture - Cosmetics - Food - Nutraceuticals

driven by the needs of the market. In these samples, the relationship between the structure and function of the polymers is well controlled and, therefore, are more suitable for the development of high valuable products. These chitosans are now increasingly appearing in the marketplace produced by companies (Novamatrix AS, Primex EHF, Ynsect, Heppe Medical Chitosan GmbH, InFiQuS S.L. among others) with expertise in the field of purified chitin and chitosan production. Thanks to this second chitosan generation, new products with application in different fields are emerging (see section 4). Moreover, as it will be explained in the next section, the regulatory framework has noticeably changed after their appearance in the market.

The chitin and chitosan research community is becoming more and more aware of the requirement of a third chitosan generation in which we will be able to produce exceptionally controlled samples, that is, chitosan with very low polydispersity or even monodisperse chitooligomers and with defined patters of acetylation. These samples will allow us to establish the cellular mechanisms that explain chitosan bioactivity and therefore they will be tremendously useful to develop specific chitosan based products in medicine and pharmacy. The advantages and disadvantage of each chitosan generation are shown in Table-2.

3. CHITIN AND CHITOSAN MARKETS

Global chitin and chitosan market is expected to witness significant growth in the following years due to the strong demand in various end-use industries, such as water treatment, pharmaceuticals, medical, food and beverage industry, and cosmetic industry. The market will be also driven by the increasing demand for natural based products in textile manufacturing and agricultural chemicals (Global Chitosan Market 2015-2019 report).

Chitin, chitosan and oligomers prices depend on the quality and physico-chemical properties of the polymers. In the low-end market, with products developed for waste water treatment, some agriculture uses and paper industry prices are around 9 USD/Kg. The prices can reach hundreds or even thousands of dollars per kilogram in the high-end market (chitosan for uses in pharmacy, biomedicine or cosmetics).

Depending on the final application chitin and chitosan are classify in three large groups according to the purity requirements: i) Technical grade chitosan to be used in agriculture and waste water treatment; ii) pure grade to be used in food and beverage, and cosmetics, and iii) ultra-pure grade to be used in pharmacy and biomedicine.

Ultra-pure chitosan is less common in the market than technical and pure grades since their production requires a strict control of the polymer isolation using high quality raw material (low contaminants in the exoskeleton) and a detailed sample characterization. From an economical point of view, this control is costly and the vast majority of the samples belong to low-end market since they are currently the most demanded ones.

Asian countries, headed by Japan and China, dominated the chitosan market over the past few years owing to the abundant availability of raw material. In the coming years, India and Korea are expected to witness high growth in terms of demand owing to rapid growth of end-use industries, including food and beverage, cosmetics, personal care and agrochemical. Europe and North America are expected to witness significant growth owing to increasing consumer demand for bio-based products.

4. INTRODUCTION OF CHITOSAN BASED PRODUCTS IN THE MARKET

The major impediment to launching chitosan-based products to the market is the legal regulation. This explains why in some markets the presence of chitosan based products are more prominent than in others.

For instance, the use of chitosan as a food additive was approved in Korea and Japan more than 20 years ago. Chitosan has been included as one of the thirty seven generic health/functional food ingredients in Korean Health/Functional Food Act and the Ministry of Health, Labour and Walfare of Japan has accepted chitosan as Foods of Specified Health Use (FOSHU). The requirements for FOSHU approval are summarized below:

- Effectiveness on the human body is clearly proven;
- Absence of any safety issues (animal toxicity tests, confirmation of effects in the cases of excess intake, etc.);
- Use of nutritionally appropriate ingredients (e.g. no excessive use of salt, etc.);
- Guarantee of compatibility with product

specifications by the time of consumption;
- Established quality control methods, such as specifications of products and ingredients, processes, and methods of analysis.

On the contrary, chitosan has not been included as a food additive in the general list of the Food and Drug Administration (FDA) or the European Food Safety Authority (EFSA). Currently, chitosan is included in the Codex Alimentarius as antifoam in juices and nectar.

As a dietetic supplement and taking advance of a more permissive legislation, there are several products in the European market, such as ChitoClear® (Primex ASA, Norway) that was recognized as grass in the USA in 2001. The use of glucosamine hydrochloride from Aspergillus niger and the use of a commercial product based on chitin-glucano (KiOnutrime-CG™) as a dietetic supplement have been positively evaluated by the EFSA in several scientific opinion documents of the Panel on Dietetic Products Nutrition and Allergies published in 2009 and 2010, respectively.

In agriculture, chitosan has been recognized as basic substance by the European Commission, which means that now chitosan products in agriculture can be used without the need of toxicity studies and registration processes (Spanish Official Bulletin, 2014). In the USA, the use of chitin and chitosan as pesticides is regulated by the United States Environmental Protection Agency (Bautista-Baños, et al., 2016).

Chitosan regulation in medicine and pharmacy depend on the final use as excipient, active ingredient

Table-3: Chitosan-based Products in the Market

Use	Comercial name	Company
Biomedicine	Reaxon® nerve guide	Medovent GmbH
	Chitosan-FH02®	Medoderm GmbH
	Beschitin®	Unitika Ltd
	ChitiPack® S	Eisai Co Ltd
	Celox TM	MedTrade Products Ltd
	Chito-SAM TM	Sawyer Products, Inc
	HemCom®	Tricol Biomedical Inc
	Chito-flex®	Tricol Biomedical Inc
Textile	Chitoskin™	Tidal visión Inc
	Diabetic chitosan socks	+MD TM
	Crabyon®	Swicofil AG
Water treatment	Storm-Klear Gel-Floc™	Natural Site Solutions Llc
Pharmacy	Betalfatrus	ISDIN Laboratories SA
Food industry	Chitoseen™-F	SIVEELE B.V.
	QiUP	Perdomini-IOC S.p.A
	ChitoFresto	PT Biotech Surindo
Nutraceutical	Chitosan gold Tea	KITTOLIFE Co Ltd.
	KiOcardio®	Kytozyme SA
	Liposan Ultra	SAFIC ALCAN SA
	ChitoClear®	Primex EHF
	KiOnutrime-CG™)	Kitozyme SA
Cosmetics	Hydamer™ CMF/CMFP	Chitinor AS
	HydamerTM DCMF	Chitinor AS
	HydamerTM HCFM	Chitinor AS
	CT-2 NYLON SP-500	Kobo Products, Inc.
	Iden Bee propolis-body lotion	Iden International Inc
	Iden Bee propolis-body wash	Iden International Inc
Agriculture	Biorend®	Idebio S.L.
	ChiFarm	PT Biotech Surindo
	Softguard	Leili-Canada Oceanic Inc.

or medical device. In 2002, the use of chitosan hydrochloride as excipient was approved by the European Pharmacopeia and more recently, in 2011, chitosan itself has been approved by the US Pharmacopeia. Unfortunately, eventhough some specific chitins, chitosans and oligomers have several biological activities as shown in Table-2, the use of chitin, chitosan or their oligomers as active ingredients is not yet approved. Regarding medical devices, the American Society of Testing Materials (ASTM) has launched several guides covering different aspects of the use of chitosan in biomedical and pharmaceutical applications (Guides F2103-11, Guide F2260-12 and Guide F2602-13). Although the legislation issues are being a bottle neck to the launching of chitosan-based products to the market in biomedicine and pharmacy some products are reaching the market as medical devices or as para-pharmaceutical products. For instance, hemostatic dressings (HemCom®, Chito-flex®, Celox TM, Chito-SAMTM) or a nail lacquer to nail psoriasis treatment based on chitosan have been successfully launched to the market. In Table-3, several examples of commercial chitosan-based products with applications in different fields are summarized.

5. CONCLUSIONS

Chitosan is a natural polymer with very interesting technological and biological properties. Over the past decades, it was predicted as a significant development of chitin and mainly chitosan-based products. However, the launching of chitin or chitosan-based products in the market has been very irregular due to issues at the commercial level and public sector.

Traditional uses of chitin and chitosan in the low end-market are well established, the low regulatory pressure over these products and the small effect of chitosan physico-chemical properties in the final performance of the product allow the use of large amounts of poorly characterized polymer with a competitive price.

In the last years, an extensive research has been carried out which has permitted a better knowledge of the relationship among physico-chemical characteristics and properties of these polymers. This so-called functional characterization of chitosan has driven the regulation of these polymers by several organizations in different countries.
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The more controlled production and the characterization of these samples increase the final price of the polymer and, therefore, its commercial use is limited to the high-end market products. These products developed for the food, biomedical, pharmaceutical or cosmetics industry need to fulfil strict regulatory aspects.

The better knowledge of the relationship among chitin, chitosan and oligomers physico-chemical properties and their biological properties is helping to boost their legal status. This improvement of the regulatory aspects allows us to predict a flattering future of the chitosan based products since one of the major impediments is the lack of regulation in high-end valuable applications, such as biomedicine, pharmacy or food industry.

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SCIENTIFIC PERSPECTIVE ON SUSTAINABLE DEVELOPMENT GOALS FOR PAKISTAN

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ABSTRACT

There are a total of seventeen Sustainable Development Goals[1] (SDGs) adopted by the United Nations for 2016-2030. These SDGs are greatly interlinked, and achievement of some depends on others. Each SDG has its own significance for Pakistan, starting from 'No Poverty and Zero Hunger' the SDGs put emphasis on Good Health and Well-Being; Gender Equality; Clean Water and Sanitation; and Reduced Inequality. Achievement of all these goals can become possible due to Quality Education; Decent Work and Economic Growth, based on Industrial Development, Innovation and Infrastructure, and Affordable and Clean Energy. Once achieved, these goals can lead to achieving other goals on Responsible Consumption and Production; Sustainable Cities and Communities; Climate Action for Life below Water and Life on Land. The aggregate effect of all these could be Peace, Justice and Strong Institutions, and national and international Partnerships.

Keywords: *Sustainable Development Goals, SDGs, Renewable Energy, Circular Debt, PEPCO, WAPDA unbundling, NTDC, NEPRA, OGRA.*

1. INTRODUCTION

Imagine the world in 2030, with each of the Sustainable Development Goals (SDGs) fully achieved in each country. People all over the world would have achieved by then:

- Human Dignity;
- Economic Progress;
- Well Preparedness for Climate Change;
- Sustainable Natural Ecosystems and Environmental Processes;
- Collaboration beyond Boundaries.

To complete this epic journey, each SDG needs a separate study to find:

- Implementation requirements and procedures; and
- Financial needs for each SDG implementation plan.

This calls for a review of the Millennium Development Goals (MDGs), its procedures, its funding sources, and its shortcomings. Most developing countries, including Pakistan, were unable to meet most of the MDGs. The main purpose of the MDGs designed for 2000 to 2015 was to design quantifiable targets for the developing countries to overcome poverty, hunger and disease, and reach economic and environmental sustainability in their respective countries. The SDGs are an extension of the same process whereby the fundamental aim is to end poverty in the developing countries, while tackling environmental degradation and climate change. In September 2015, "2030 Agenda for Sustainable Development" was adopted at the United Nations Sustainable Development Summit. The adoption of SDGs was connected with the United Nations Framework Convention on Climate Change (UNFCCC)'s Conference of Parties (COP-21), Paris, France, where Intended Nationally Determined Contributions (INDCs) – for curtailing fossil-fuel carbon emissions from the economic processes – were submitted by each country, including Pakistan. The INDCs by Pakistan includes quantifiable information on:

- The reference point, i.e., a base year;
- Timeframes for implementation;
- Planning processes;
- Assumptions and methodological approaches including those for estimating and accounting for anthropogenic greenhouse gas (GHG) emissions and removals;
- How Pakistan considers that the country's INDCs is fair and ambitious, in light of its national circumstances.

When it comes to SDGs, it is understood that countries cannot pick and choose SDGs; they come as a collective package from the UN. That is the reason why research papers explain the scientific research options and identify funding resources for SDGs for Pakistan. The SDGs that have been chosen for this paper for detailed analysis are:

- Affordable and Clean Energy (SDG-7);
- Decent Work and Economic Growth (SDG-8);
- Industry, Innovation and Infrastructure (SDG-9);
- Responsible Consumption and Production (SDG-12);
- Climate Action (SDG-13).

[1] "2030 Agenda for Sustainable Development" consisting of seventeen Sustainable Development Goals was adopted at the "United Nations Sustainable Development Summit" in September 2015 held at UN Headquarters in New York, USA.

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For each of these SDGs, the discussion is to focus on the following two issues:

- Science and Technology options for SDGs in Pakistan;
- Investment, Finance and Economic Management for SDGs in Pakistan.

Alongwith the United Nations, World Bank, and Asian Development Bank, many international organizations like International Institute for Sustainable Development-IISD (IISD Reporting Service, 2016) and the International Institute for Environment and Development-IIED (IIED's Human Settlements Group, 2016) have highlighted SDGs in their global development agenda.

Local organizations like Pakistan Institute of Development Economics-PIDE (PIDE, 2015) and Sustainable Development Policy Institute-SDPI (SDPI, 2015) are putting a lot of efforts into bringing the SDGs to the forefront, so that development policies and financing for these policies include SDGs. In Pakistan, efforts are being made by the present Government to include SDGs along with Vision 2025 and China Pakistan Economic Corridor (CPEC) into mainstream economic planning.

The starting point for identifying the implementation possibilities for SDG-7 on Affordable and Clean Energy in Pakistan is based on the reality of energy sector of Pakistan and its effects on economic growth in the country. A brief history of Pakistan's energy sector is as follows.

1.1 History of Energy Sector in Pakistan

Starting from Karachi, K-Electric was incorporated in 1913. In 1952, the company was taken over by the Government of Pakistan. During 1994 to 2005, Pakistan Army managed K-Electric. In 2005, K-Electric was privatized and sold. In 2009, K-Electric was sold to international owners. In 2016, electricity demand still exceeds electricity supply in Karachi.

In Balochistan, Gas was discovered in Sui in 1952, and production and distribution started in 1955. Gas is managed in Pakistan by Sui Northern Gas Pipelines Limited (SNGPL) founded in 1963 and Sui Southern Gas Company (SSGC) founded in 1954. In 2002, the Oil and Gas Regulatory Authority Ordinance established Oil and Gas Regulatory Authority (OGRA), in Pakistan. Gas rationing and gas load-shedding in winters is an annual feature for last many years in Pakistan.

Water and Power Development Authority (WAPDA) of Pakistan was established in 1959. Mangla and Tarbelas Dam were inaugurated in 1967 and 1976, respectively. PEPCO was incorporated in 1998 and became functional in 1999. NEPRA was established under Pakistan National Electric Power Regulatory Authority Act during the same time. National Transmission & Dispatch Company (NTDC) was established in 1998. In 2007, Pakistan Electric Power Company (PEPCO) was independently formed by splitting WAPDA. Hydropower management stayed with WAPDA, while PEPCO was formed for management of thermal power in the country. However, currently both hydropower and thermal power are not adequate to meet the present demand for electricity in Pakistan.

In 1985, World Bank, WAPDA and the Government of Pakistan signed a Tripartite Agreement for facilitating private sector to provide thermal electricity in Pakistan. The process of commercialization and privatization of the energy sector, i.e., WAPDA unbundling in Pakistan began under the 1992 Strategic Plan. Under the 1994 Power Policy, Independent Power Producers (IPPs) were invited to provide electricity to consumers in Pakistan. A new problem of circular debt has come up since then.

WAPDA unbundling has already taken place, resulting in multiple electricity production, transmission and distribution agencies. The next and more crucial process of privatization and commercialization of these multiple GENCOs and DISCOs in the electricity supply sector is yet to be completed. Although the system has been unbundled and segregated, it is still in the control of the federal government (Khalid, 2014). This slow reformation in the electricity supply sector has highlighted the shortcoming of the "standard template" that was applied to many developing countries by the multilateral development agencies under the pretext of "new neoliberal policies". This "neoliberal economic theory" envisions electricity supply under corporate control and commercially viable rather than under public governance (Kessides, 2013). A very important pre-requisite to this process is preparation of the banking sector to finance the transition from public sector to private energy supply sector (Yi-chong, 2006). The depth needed for the financial infrastructure is missing in Pakistan and many other developing countries in comparison with financial sector's involvement in the energy sector in the USA, UK and EU. The currency markets, bonds markets and the stocks markets need to prepare before this transition is initiated. Keeping in view the

capabilities of the country's banking and currency, as well as stocks and bonds markets, the ownership of the restructured power sector of Pakistan must be transffered to the corporate sector very systematically and slowly. With each province preparing its own privatization plan, a step-wise method must be applied where each province must start with assessment of its provincial banks, both public and private, and then float bonds and shares for its energy sector agencies for shared ownership that should culminate in moving ownership of energy supply sector to commercial and private corporate sectors.

In 1974, Pakistan's Nuclear programme was given impetus the then President, Zulfikar Ali Bhutto. Initiation of the construction of Kalabagh Dam was the most important event that did not take place during the eleven years of General Zia-ul-Haq's regime (1977 to 1988). Kalabagh Dam exists only on the drawing board. Established in 1956, the Pakistan Atomic Energy Commission (PAEC) has designed Karachi Nuclear Power Plant (KANUPP) to provide electricity to Karachi city and surrounding areas, while Chashma Nuclear Power Plant (CHASNUPP) is designed to provide electricity to select areas in the Punjab Province. This technology of nuclear energy-based electricity plants is yet to reach KPK, Balochistan and Sindh Rural.

Later, Benazir Bhutto was twice Prime Minister of Pakistan (1988-1990 and 1993-1996). There was no chance for Kalabagh Dam approval during her regime, but she linked Sindh, particularly, interior Sindh to the same existing electricity grid, adding new demand load for electricity supply.

During 1990 to 1993 and then again during 1997 to 1999, Mian Muhammad Nawaz Sharif was the Prime Minister of Pakistan. Two things happened; Punjab, along with the rest of the country faced regular interruption in electricity supply in the form of load shedding and, in 1998, Pakistan developed weapon grade nuclear technology.

From year 2000 to 2013, Pakistan continued to face electricity load shedding and gas rationing. Successive governments have tried but electricity supply is insufficient for meeting the electricity demand in the country (NEPRA, 2015). Similarly, gas supply and CNG supply are not sufficient during the months of winter.

The reform needed in the energy sector is to have a consolidated energy agency in Pakistan that identifies energy demand (electricity and transport); size and location, three months in advance and lets the suppliers (government and corporate sector) know about that so that arrangements are made to match energy supply with energy demand in Pakistan. Fragmentation in Pakistan's energy sector governance is a hindrance in implementing this reform in Pakistan.

"Energy-Consumption" is different from "Energy-Demand" in an energy-deficit country, like Pakistan. In energy-balanced and energy-surplus countries, energy-consumed is equal to energy-demanded (Mallick, et al., 2000). In these countries, energy demand is estimated in advance and energy infrastructure ensures this energy supply; so that, energy supply is sufficient to meet the energy demand. In these countries, energy-consumed is equal to energy-demand; in addition, these countries ensure strategic energy reserves.

Financing of the energy sector requires substantial resources. Pakistan has insufficient financial resources to keep its energy sector operational. Pakistan's energy sector has two types of financial problems:

- Circular Debt – specifically for fuel purchase for thermal electricity sector; and
- International Debt – for both hydropower construction and purchase of fuel for thermal power infrastructure.

When it comes to building new hydropower infrastructure, Pakistan has neither the political will nor the financial resources to create it nationally or at the provincial level. The whole country has to seek huge international loans and debts on market interest rates to build the hydropower infrastructure. Similarly, the thermal sector was run on imported oil until recently. Arrangements have been made to run the thermal energy sector on imported LNG along with imported oil. There is some discussion about future plans for running thermal energy on imported coal, as well. This means that to run the thermal energy sector of this size in Pakistan, there is constant need for imported oil, LNG, and coal. All this needs money.

If Pakistan starts to print energy sector money (something similar to WAPDA Bonds for the thermal sector) these printed bonds or money could pay for purchase of dollars or whatever currency is used for making payments for oil, LNG and coal. This could result in devaluation of currency with each purchase

due to trade imbalance, if the other country is not buying exports of same financial value from Pakistan. The other option is to take loans for purchase of oil, LNG and coal. This means that at the end of that year, loan provider will have to be provided with loan payback plus interest incurred. Fuel purchased using loan money is much more expensive, due to additional interest. Using-up money in circulation exerts pressure on local commercial banks in Pakistan and eventually on State Bank of Pakistan. The Government of Pakistan is using up cash in market for paying for circular debt.

To weigh the future prospects, it is important to see which SDG will take Pakistan's economy to a higher level. In the next sections, each of these SDGs is analyzed for their purpose and scientific underpinnings and also for identifying financial priorities for the next fifteen years.

2. THE PURPOSE OF SDGs

The two most important SDGs are: No Poverty and Zero Hunger. These SDGs form part of conditions that will fulfill the basic requirements for human dignity by 2030. It is of utmost importance that these two conditions are fulfilled along with: Good Health and Well-Being; Gender Equality; Clean Water and Sanitation; and Reduced Inequality. Improvement in life expectancy rates and better quality of living for all depends on each of these SDGs. With better social cohesion due to reduced inequalities, better economic outlook could be envisaged.

To reach this level of human dignity and human security, economic progress needs to be made so that Quality Education is provided; that makes Decent Work and Economic Growth possible, based on Industry, Innovation and Infrastructure, and Affordable and Clean Energy accessible to all. Here SDG on Affordable and Clean Energy will play a pivotal role. The progress on all SDGs hinges upon this SDG. As educational institutions provide nationally and economically appropriate education and training, this will result in improved labour markets and dynamic economy. As country brings improvement in the energy sector, it will head in the direction of sound industrial development and scientific innovation resulting in better and environmentally appropriate infrastructure.

Along with those addressing human dignity, human security and economic progress, the SDGs that need appropriate attention and funding are the SDGs relating to climate change and environmental processes. As paths are set for new dynamism for economic growth, Responsible Consumption and Production will set the boundaries that will change footprints size for consumable fuels and natural resources in the future. As people would then live in the Sustainable Cities and Communities, their commute and travelling will be emission free, their indoors temperature controls will be based on innovative technologies consuming renewable energy sources. Markets for good and services will have reduced impact on the transportation system by producing many essential products in the city's periphery.

Special attention would be given to Climate Action by establishing appropriate institutions that focus on fuels and air quality in each city and industrial production areas. To keep pace with innovations in the food technology industry, scientific research institutions will be dedicated to study of Life below Water and Life on Land. Human activities have direct bearing on flora and fauna of land and water. For future sustenance in food and fuel, scientific community will need to focus attention on processes that restore and sustain the balance in ecological systems.

For national and international Partnerships, it is imperative to have Peace, Justice and Strong Institutions in countries and communities globally. The national institutions working on SDGs will have two-fold responsibility: to implement SDGs nationally and to have constant contact with regional and global institutions performing similar duties.

2.1 Scope for Scientific Research and Innovation

Reduced Inequality will play a fundamentally important role along with Zero Hunger and No Poverty. To improve yields from agriculture, farmers need technology, energy resources and finances. Inequality in access to technology, energy resources and finances hinders speed on which a farmer can improve agricultural yields from the same field. Agriculture Technology Experts, Engineers, Scientists and Agriculture Finance Experts will need to work with this triangle: No Poverty; Zero Hunger; and Reduced Inequality.

Good health and well-being, gender equality, clean water and sanitation are all very closely linked. In most rural areas of Pakistan, women are responsible for fetching water for the household. As a result of Gender Equality, women of the household are equally healthy

and nourished enough to take care of their responsibilities efficiently. Healthcare and sanitation facilities should be available to all women in a rural community, particularly, in the form of mother and child health centers.

As the masses have adequate food crops, with nutrition and health facilities in both rural and urban areas of Pakistan, they would be at an acceptable level of Human Dignity. Then the focus shifts to rapid Economic Progress and Engine of Growth, i.e., Education, Employment, Innovation and Energy Resources. The SDG on Quality Education is closely linked with SDG on Decent Work and Economic Growth. Both these SDGs are dependent on SDGs on Industry, Innovation and Infrastructure and Affordable and Clean Energy. Quality Education builds a base for Industry, Innovation and Infrastructure. No economic activity can take place without readily available energy sources; therefore, Affordable and Clean Energy is central for Decent Work and Economic Growth in Pakistan, from now to year 2030. Scientists, engineers, innovators and financial experts will need to team-up to build a system of quality educational institutions that will bring Innovation to Industry, Infrastructure and Energy sectors of the economy. These could take Pakistan to sustained economic growth to the year 2030.

Innovative infrastructure will result in achieving the SDG on Sustainable Cities and Communities and innovation for economic growth will help in achieving the SDG on Responsible Consumption and Production. Scientist, engineers and financial planners will need to build the base for technological innovation that will result in Sustainable Cities and Communities. The defining trait of these Sustainable Cities and Communities would be Responsible Consumption and Production. Energy consumption and waste disposal are the two biggest urbanization problems along with transport congestion. As most of the commodities that are needed in high population density areas are produced elsewhere, these are transported to the city centres. The most responsible innovation would be to produce most of the commodities needed in the areas near or inside the cities. This would reduce the transportation costs and transport-based fuel emissions. Town planners, economic development experts, corporate sector and transport sector experts will need to get together to design new cities and retrofit existing cities with Responsible Consumption and Production and efficient transport patterns for Sustainable Cities and Communities.

The SDG on Climate Action is becoming center-stage as climate change impacts are becoming visible. Changes in biodiversity of flora and fauna of land and marine ecosystems have direct repercussion on the food that humans consume. Ocean coral bleaching, storm-surges, coastal cyclones and unusual terrestrial temperatures and precipitation are all signs that need to be reckoned and dealt with. Air pollution has direct impact on human and animal health and in severe cases for trees and other flora. Fossil fuels and carbon emissions are central to climate change discussions. Air pollution comprising of particulate matters, smoke and smog persists in most high density urban centres. Climate action will need to focus on air quality for urban centres. The improvement in the transport sector will result in air quality improvements. Water quality matters for drinking water and also for water used for crop and vegetable growing. Toxic heavy metals in water could enter food chain and cause health problems. For sustained Life Below Water, oceans, rivers and lakes will need quality management practices. Life on land, with all its biodiversity, needs eco-friendly economic development plans, where town planning includes green spaces for seasonal movement of animals and other creatures. A wide spectrum of scientists, technical experts and natural resources consumers/managers, like farmers and fishermen will need to stay attuned with the signs and symptoms of deterioration in both flora and fauna and put all efforts to maintain a healthy ecosystem.

With Peace, Justice and Strong Institutions in the country, Partnerships for the Goals will be easy to build. The scientific and technical experts in their respective fields would then have ample opportunities to collaborate at national and global levels. The outputs would be innovative and efficient technologies for each of these SDGs.

3. FOCUS AREA FOR PAKISTAN

Although all seventeen SDGs have their own individual importance, but SDG number seven, i.e., Affordable and Clean Energy, plays a pivotal role. This SDG has separate descriptive for 'Energy', 'Affordable' and 'Clean'. Sufficient supply of energy resources with well-managed energy pricing mechanism will make energy resources affordable in Pakistan. The reason for selecting this SDG is that as Pakistan ensures 'Affordable' and 'Clean' energy; it will also have to ensure the availability of energy. With young and increasing population, with ever-increasing energy-demand and with responsibility to ensure GDP

growth rates from 4% to 7%; energy supply needs to increase on an increasing rate. In Pakistan, present energy production capacity is between 15,000 MW to 25,000 MW, this will need to be increased from 50,000 MW to 60,000 MW by year 2030 to turn Pakistan into an energy-sufficient and energy-balanced economy (International Resources Group, 2011).

Presently, in Pakistan, the issue of fuel subsidies is also a matter of discussion. Particularly, for developing country like Pakistan where value of own currency depreciates as additional printed money hits the markets due to fuel subsidies and circular debt. This creates two problems:

i. On subsidized rates, consumers demand more energy resources than they can normally afford;
ii. Government becomes part of the market mechanism as it provides subsidies to energy consumers and grantees fuel supply to energy producers in the private sector. It also guarantees electricity purchase from the Independent Power Producers (IPPs).

In most instances, unusual market shocks, like spikes in oil prices, compel the Government to provide a buffer of subsidies to energy consumers. Without subsidies, persistently high international prices of energy commodities reduce national economic processes proportionally, contracting GDP growth, but constant provision of energy subsidies could cost national exchequer reduction in wealth and hence additional tax to pass-on this burden of subsidies. Subsidy is the amount that is not charged in bills to energy consumers and that expense is absorbed internally by the government. So the subsidy buffer for energy consumers has its direct and indirect costs. For many Governments in the developing countries 'Affordable Energy' for consumers, based on subsidies is a big economic and political risk.

When it comes to 'Clean Energy' it means energy sources that are not dependent on fossil fuels or are very efficient fossil fuels with very low carbon emissions. For a futuristic energy innovation plan to reach year 2030, this is a technologically intense SDG. To set the energy consumption path to reduced carbon emissions, clean energy resources are imperative. The two other processes that can go parallel for reducing carbon emissions are: carbon sequestration and carbon capture and storage. In most instances carbon emissions result in direct air quality deterioration, particularly, in the urban centers. With 'Clean Energy', urban centres would improve their air quality to have positive health benefits. Therefore, 'Affordable and Clean Energy' is the central resource that will provide the impetus for positive results towards all other SDGs. Globally, all economies are dependent on fossil fuels. This means that within a brief period of fifteen years, all global and national economies will need to have a significant shift away from fossil fuels towards renewable energy sources, reducing carbon emissions along the way.

Sufficient supply of Affordable and Clean Energy will result in Industry, Innovation and Infrastructure contributing to Decent Work and Economic Growth. This will set the path for Responsible Consumption and Production; Sustainable Cities and Communities; and Good Health and Well-Being. This will in turn, provide meaningful results to No Poverty and Zero Hunger. People will be provided with Quality Education and Clean Water and Sanitation. All these will result in Reduced Inequality; Gender Equality; and Peace, Justice and Strong Institutions. It means that Affordable and Clean Energy will bring economic progress that will result in better quality of life and improved human dignity.

Affordable and Clean Energy; Decent Work and Economic Growth; and Responsible Consumption and Production are dependent on five processes:

i. Upgrading energy sector by attracting sector specific investment;
ii. Bringing macroeconomic stability to Pakistan, create effective, strong and supportive financial institutions for attracting investment;
iii. Improving transport infrastructure for efficient links with national and international markets;
iv. Greening of the industrial and agricultural production processes for reduced emissions;
v. Channeling scientific research at higher education centres towards SDGs implementation.

These processes will ensure strengthening of the energy sector; banking and the financial sectors; transport sector; industrial and agricultural productivity; and expansion of markets and trade. This will also ensure that research at the academic scientific institutions is connected with the process of implementation of SDGs in the country.

To make energy sector 'Affordable' with an increased proportion of "Clean Energy", the first two processes are linked with the fifth process. As Banks and other financial institutions build investment base to strengthen energy sector, the higher education centres must provide innovative ideas, and science

and technology support to this SDG. Here, the process needs to be started to help identify financial resources for scientific research and development for achieving this SDG.

The link between industry, chambers of commerce and higher education centres will need to efficiently channel scientific innovations and technological improvements for:

- Energy efficiency of fossil fuels;
- Market integration of renewable energy;
- Intensify hydropower and other renewables for energy consumption;
- Enhance productivity for the industrial and agricultural sectors while reducing emissions;
- Making transportation sector environmentally friendly.

The agenda for using science and technology for SDGs needs to be based on systematic allocation of funds for specific sectors of the economy. Science and technology must become an integral part of the SDGs implementation in Pakistan. Therefore, higher education centres should coordinate with market forces to channel and develop technologies that enhance productivity and improve efficiency. For using science and technology for SDGs, higher education centres will need to design new research and development centres for SDGs. The core values, goals and objectives of these centres of excellence must highlight links with SDGs. A dedicated system of academic research should also be made to focus on the outcomes and results of SDGs in the country.

Affordable and 'Clean Energy' also supports Climate Action helping in ensuring pristine 'Life below Water' and provide safeguards for biodiversity and 'Life on Land'. This could take Pakistan on a path to being well-prepared for Climate Change and with 'Sustainable Natural Ecosystems and Environmental Processes'.

In many instances, 'Affordable Energy' also means efficient. For efficiency, the standard measure is GDP produced per unit of energy consumed. As energy efficiency increases, its carbon emissions reduce. This path of low-carbon has its limits, but could help reduce the fossil-fuel consumption. Two of the most important Climate Actions for reduced carbon emissions are:

- Improvement in efficiency and reduction in emissions in fossil fuels;
- Increase in demand and increase in production capacity of renewable energy technologies, like those used to harness energy from solar; wind; hydropower; geothermal; and ocean-waves sources. These need investment in both infrastructure and machineries. Development of these 'Clean Energy' technologies depends on local and international investment interest. Strong, well-supported and effective financial institutions will open channels for investment to reach these innovative renewable energy technology options.

4. TECHNOLOGIES FOR SDGs IN PAKISTAN

The technologies that will take a country, like Pakistan, to a future where all the seventeen SDGs are met, matter the most. To develop or purchase these technologies from abroad, huge amounts of funds are required.

Using SDGs: For 'Affordable and Clean Energy' and 'Industry, Innovation and Infrastructure', a plan could be chalked out for funding SDG-led economic growth in Pakistan. To align the SDGs and financial needs nationally and provincially, it can be said that financial resources are needed for developing the energy sector, particularly renewable energy to be available at affordable prices. This then connects to financial resources needed for industrial development; innovation in science and technology, and investment needs for infrastructure development in the country. If each province provides energy sources that are in abundance and are easy to develop provincially, a systematic financial planning can be designed for each of the provinces. Four types of energy resources are available in Pakistan:

i. Hydropower;
ii. Fossil Fuels;
iii. Nuclear;
iv. Renewable Energy.

Four different types of government departments are working for development of these technologies and designing projects within these four domains (Box-1).

Punjab province of Pakistan is an interesting case; it has no hydropower of its own and is heavily dependent on rivers flowing from Kashmir. Punjab has true potential for renewable energy, particularly, solar energy and bio-fuels. There is future potential for electricity from nuclear energy, but stringent safety measures will need to be applied, if new sites near urban centres are to be developed.

Box-1: Pakistani Departments/Institutions Working in Different RETs

Box-1: Pakistani Departments/Institutions Working in Different RETs			
Hydropower	**Fossil Fuels**	**Nuclear Energy**	**Renewable Energy**
The Water and Power Development Authority (WAPDA) National Transmission & Despatch Company (NTDC)	Pakistan Electric Power Company (PEPCO) Private Power and Infrastructure Board (PPIB) Independent Power Producers (IPPs) Karachi Electric Supply Company (KESC) Oil and Gas Development Company Limited (OGDCL) Hydrocarbon Development Institute of Pakistan (HDIP)	Pakistan Atomic Energy Commission (PAEC) Pakistan Institute of Nuclear Science and Technology (PINSTECH) Pakistan Institute of Engineering and Applied Sciences (PIEAS) Khan Research Laboratories (KRL) Pakistan Nuclear Regulatory Authority	Alternative Energy Development Board (AEDB) Pakistan Council of Renewable Energy Technologies (PCRET)

The future energy projects associated with mega-projects, like China Pakistan Economic Corridor (CPEC); Iran-Pakistan (IP) Gas Pipeline; Central Asia South Asia Electricity Transmission and Trade Project (CASA-1000); and Turkmenistan-Afghanistan-Pakistan-India (TAPI) gas pipeline paint a rosy picture for all, particularly, the Punjab province of Pakistan, in terms of electricity and energy supply. What matters most is that Punjab is most probably populated by a hundred million to a hundred and fifty million people. Their energy demand is also increasing on an increasing rate. Imported fossil fuels and international supply of electricity is planned for the future for this ever-increasing energy and electricity demand in the Punjab province.

What could eventually be added to this ensemble of energy supply and electricity supply project is imported electricity from nuclear sources from Iran and China. As long as the nuclear electricity generation plants are on the borders between China and Pakistan, and Iran and Pakistan, it would ensure timely supply and stringent maintenance of machinery and equipment. As most of this energy supply system will be passing through Khyber Pakhtunkhwa (KPK) and Balochistan, a future agenda of energy supply and sharing will need to be devised between provinces and the capital.

When it comes to KPK, there is huge potential for Hydropower in KPK, with resources like Indus, Swat, and Chitral rivers. Main focus on developing hydropower in KPK will produce surplus electricity that can then be transmitted and dispatched to other provinces. KPK also has a huge potential for discoveries of fossil fuels, such as Oil, Gas, and Coal. The new and emerging trends in KPK for renewable energy sources are for Solar; Wind; and Bio-Fuels. One reason given for solar technology proliferation in KPK and Waziristan is that it is a private source of energy with one-time investment and no recurring bills from the government. It is hoped that CASA 1000 and TAPI, both passing through KPK, will bring new electricity and energy sources to Pakistan and India, particularly, to their Punjabs.

Sindh and Karachi have very different energy demand and supply relationships with the Center. Karachi is a coastal city and has access to imported fuels. This gives Karachi an advantage that it can produce surplus energy and sell it to rest of the country, particularly, to Sindh and Punjab. An intensive energy and electricity production system could be developed by combining Karachi-Hub-Gadani sites. As administration from both Sindh and Balochistan provinces would be involved, therefore, an inter-provincial energy/electricity coordination committee could be convened. Karachi already has provision for electricity from nuclear energy source that could be further enhanced in future. Sindh has huge lignite coal reserves. Scientific possibilities include below-ground on-site coal gasification. Based on this, Sindh province has a huge potential to provide surplus electricity and transport energy (converting coal to liquid fuel) to other provinces, particularly, Punjab.

Balochistan has the potential for fossil-fuel discoveries and pipelines from Iran to the rest of the country and beyond, particularly, both Pakistani and Indian Punjabs. Gwadar to China transport of fuel from the Middle East, and China to Gwadar transport of commodities will bring the biggest surge in economic growth in Pakistan. Renewable energy potential is also quite huge in Balochistan. Balochistan could sell

surplus electricity from renewable sources, particularly, solar, to other provinces. Due to severe shortage of water during the lean Monsoons, Balochistan will need to design scientifically innovative water projects for its population using technology for desalinization of seawater.

CPEC is the project that will involve all provinces of Pakistan. Science and technology for SDGs and CPEC will need to be linked during the next fifteen years. With the investment in CPEC infrastructure development project in Pakistan, efficiency will improve in the transport and energy sectors of Pakistan. Trade, commerce and industry will function at a regional level. The science and technology for SDGs could link higher education centers with industry and chambers of commerce as these expand due to CPEC. Fuels and efficiency of fuels will get precedence in research and development as transport, industrial and energy sectors come in focus. This is where renewable energy technologies could also enter the expanding economic system as part of CPEC. The new trade routes built on traditional trade routes will bring new demands for commerce and trade. Productivity enhancing technologies will bring industrial and agricultural productivity and quality to international market standards, and would help in meeting demands in a timely manner.

5. FINANCING OF TECHNOLOGIES FOR SDGs

To make the energy technologies needed for SDGs investable and to make electricity and transport energy affordable during the next fifteen years in Pakistan, there is a need for systematic investment and financial planning in energy sector infrastructure. Development of financial, banking and investment sector will bring new impetus to infrastructure development for energy and transport sectors. Increased financial allocation to science and technology for energy and transportation sectors will increase the role of higher education institutions and improving the economic outlook for Pakistan.

There is a strong push for privatization and commercialization of thermal energy sector of Pakistan. The hydro-power, particularly large dams, are still not commercially viable to be privatized at the construction phase. Once the dams are constructed by the federal government and its international loans paid, the commercial entities like commercial banks could take-up partial ownership of operations, maintenance and some other activities.

Renewable energy has the most potential for commercial activities in Pakistan. In most cases, investments are huge and result in immediate financial returns on electricity produced. The down side to all this is that solar energy infrastructure (without storage batteries) is not a hundred percent efficient, because of reliance on only daylight hours. Additional expense of batteries enhances efficiency but also incurs installation costs.

To provide 'Affordable and Clean Energy' to off-grid areas, far away from urban centers could be a potential market for solar panels and wind turbines. Government loan or investment projects or personal or commercial investments will bring these renewable technologies to KPK and Balochistan very quickly. Punjab, Sindh and Northern Areas of Pakistan also have high up-take potential. The higher education institutions in the country could design centers of excellence for identification and grading of renewable energy technologies, and innovations in fuel-efficient machinery and energy efficient buildings.

The SDG on 'Affordable and Clean Energy' is closely linked to the SDG on 'Industry, Innovation and Infrastructure'. The financing of science and technology for this SDG is closely connected with the SDG relating to the energy sector. In most cases, industrial productivity is energy intensive. One of the most needed innovation in the industrial sector is energy efficiency. All forms of infrastructural developments are highly energy intensive. It is not possible to achieve infrastructural development for expanding industrial sector without, first, increasing the size and efficiency of the energy sector in Pakistan. Most engineering and industrial innovations are for energy efficiency and for renewable energy equipment design.

Examples of two cities in Pakistan, Karachi and Faisalabad, can be taken. In addition to the labour and raw materials, these cities are dependent on: energy sector; transport sector; and innovations in industrial processes and infrastructure. Karachi is a port city but Faisalabad uses existing road and rail infrastructure to get fuels and raw materials to reach its industrial areas and to distribute its products, mainly cotton-based, to international markets. The crunch that both Karachi and Faisalabad have faced in recent past in the form of slowing down of their industrial growth is mainly due to reduced supply of energy resources. These industrial hubs need energy supply on an increasing rate, to keep the productivity at par with international market demands. Even highly innovative and technologically

advanced machineries cannot support the producers to compete in the international market without constant energy supply. This need for energy supply is consistent with the SDG on Affordable and Clean Energy. In next fifteen years, the achievement of the SDG 'Industry, Innovation and Infrastructure' in Pakistan will depend on the achievement of the SDG 'Affordable and Clean Energy'. This is where science and technology for SDGs could link research and development with local demand-driven processes. At the level of scientific research institutions, research focus should be concentrated on technology-driven research for fuels and energy resources. Energy efficiency in the industrial sector is one of the key components of technological innovation. Financing of these technological processes and other components of SDGs need systematic planning at government level, where corporate and banking sector is encouraged to participate.

Both CASA (Central Asia-South Asia) 1000 and TAPI (Turkmenistan–Afghanistan–Pakistan–India Pipeline) will connect electricity and gas from the West to KPK and Islamabad. Both of these projects are planned due to availability of loans. International Finance Corporation, World Bank, and USAID have specifically designed Energy Projects Financing Facilities (EPFF) for Pakistan. China is one the few countries that have interest in EPFF for Pakistan; this could also facilitate energy infrastructure development in the future. Iran-Pakistan gas pipeline is another possibility to be included under CPEC funded EPFF.

In Pakistan, monetary capabilities of the banking and currency markets, and stocks and bonds markets need to be strengthened. This will benefit the commercialization process of the ownership of the restructured electricity sector of Pakistan as it is transferred to the corporate sector. Floating of energy sector specific bonds and securities by the government, and floating of shares for energy sector agencies will bring financial boost to energy sector transition. As GENCOs and DISCOs reach their full potential, their shares and ownership could be traded at the stock markets in Pakistan.

Considering that every year about forty per cent of GDP is spent on debt services and loans repayment, other methods need to be identified for funding energy sector projects in Pakistan. Energy demand in Pakistan is much larger than energy supply. This means that if this sector is not brought to balance, all other economic activities would shrink. A separate energy sector investment plan needs to be prepared. This is where a research project funded by the Higher Education Commission (HEC) of Pakistan could be useful. Under one of the components of HEC's National Research Programme for Universities (NRPU) Project, titled 'Financial Planning for Energy Security in Pakistan: The Way Forward for Renewable Energy', the Commission has an objective to sign an MoU to design and establish Climate Change financial institution in Pakistan, titled "Climate Change Investment Bank".

Although this institution was dubbed the 'Climate Change Investment Bank', it will provide financial support for Energy Security in Pakistan (Mallick, 2015). The main focus here is to promote Renewable Energy in Pakistan by attracting investments in energy sector projects. As finances will be channeled through this institution, a clear financial accountability system will emerge. It is envisaged that each province will have dedicated investment banking structured for energy sector. This will ensure that energy projects are clearly defined in the financial terms, i.e., energy projects are made "bankable" and attractive to investors. These energy projects must have two supporting clauses to be financeable:

i. Have appropriate risk management mechanisms for potential investors;
ii. Have favorable internal rate of return (IRR).

The Climate Change Investment Bank must focus on infrastructure projects for the energy sector. Soft project components, like capacity-building, and training of technicians for technological development, will be made part of the larger infrastructure projects. Each energy project will be technology-innovation driven.

The definition of "renewable" is kept flexible by the Climate Change Investment Bank in its MoU. This is contingent upon the terms and conditions set by the investors as they provide investment funding for specific projects. As the Charter for the Climate Change Investment Bank takes its shape, the measures available to investors for covering risk will become evident. The prevailing interest rates and direction of future interest rates in the local and international market will have impacts on Net Present Value (NPV) and hence internal rate of return (IRR). As the Investment Bank becomes functional, all-out efforts need to be made to ensure that each province is provided investment by Climate Change Investment Bank for energy projects.

This is just one of many examples of new ideas that are under preparation for energy sector investment in Pakistan. Due to the close proximity of some of the SDGs with UNFCCC's COP process, it is envisaged that Global Climate Fund (GCF) will be providing funds to Pakistan for both climate change adaptation and mitigation. With SDG7 in focus, the climate change mitigation funding coming to Pakistan could support the provinces in implementing their energy sector strategies for SDGs.

6. CONCLUSIONS

When it comes to future planning for Pakistan's energy sector, Pakistan is being run by three independent political parties at the moment. This means that they have very different political agendas on future economic development in the country for Punjab, KPK, and Sindh. When it comes to hydropower, thermal power, and below-ground coal gasification technology, they all have different investment policies. KPK and Punjab might place hydropower as a priority. However, being a lower-riparian province, Sindh will oppose construction of any hydropower projects up-stream. When it comes to finding investors for below-ground coal gasification technology for the coal reserves in the Thar desert in Sindh, provincial and federal governments are not on the same page regarding investment responsibilities and financial liabilities before actual earnings and returns on the project begin.

Similarly, for the thermal energy sector, imported oil is needed to keep this energy sector running. Huge and long-term debts are being arranged to add LNG to energy-mix for thermal power generation. Future investment from China is expected under CPEC in coal-run thermal plants. Under hydropower, various dams are under construction in the northern mountainous areas; these could take another five to ten years to complete. Pakistan has a potential to increase its nuclear based electricity supply. The new and emerging technologies for renewable energy are there to invest in.

Pakistan needs to achieve SDG-7, whereby Affordable and Clean Energy is made available to all by year 2030. For this, each province of Pakistan will need to design its own individual plans and make commitments for energy sector related SDGs and related financial and implementation strategies. These need to be part of the Provincial Development Strategies; for example, Punjab Growth Strategy-2018 and KPK Industrial Policy-2016. Each year Federal and Provincial Annual Development Plans from 2016-2017 to 2029-2030 must highlight commitments to SDGs, particularly, the SDG-7. These Provincial Development Strategies and Annual Development Plans must be prepared in consultation with academia and corporate sector. The HEC of Pakistan has requested all academics with new academic research projects, to highlight the connection of their research with SDGs. This directly involves university level academics in planning and designing new technologies for achieving SDGs in Pakistan. The department within the Pakistan's Planning Commission dedicated to Poverty Alleviation, MDGs, and SDGs will need to take the responsibility of monitoring and evaluating 'SDGs Implementation Strategies' in these Provincial Annual Development Plans, and measure financial resources allocated for energy sector development in each province of Pakistan.

The SDGs that will benefit the most from the goal of 'Affordable and Clean Energy' are: 'Industry, Innovation and Infrastructure'; 'Quality Education'; and 'Decent Work and Economic Growth'. Once this is achieved, Responsible Consumption and Production; and Sustainable Cities and Communities could be designed and managed efficiently in Pakistan.

Within Pakistan and globally, intense effort is needed for reaching the SDGs: 'Zero Hunger'; 'No Poverty' and 'Reduced Inequality'. As the condition of people living in absolute poverty improves, it would become easier to focus on other SDGs, i.e., 'Good Health' and 'Well-Being', 'Clean Water and Sanitation', 'Gender Equality' and local 'Peace, Justice and Strong Institutions'. For Pakistan, climate resilient economic development and infrastructure design is a must, so that a sustained level of economic development is reached resulting in human dignity and protection of ecological and environmental processes while achieving the SDGs. Climate Action for Life below Water and Life on Land will then become achievable, nationally, as it becomes a global priority.

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ASSESSMENT OF GLOBAL CARBON DIOXIDE EMISSION AND WARMING WITH A FOCUS ON PAKISTAN

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ABSTRACT

The global emission of Green House Gases (GHGs) is on the rise since the era of industrialization (ca. 1750s), with a current global monthly average of slightly more than 400 ppmv for CO_2[#]. This has resulted in rise in mean surface temperature of Earth, commonly referred to as Global Warming (GW). The need to reduce this accelerated global emission of GHGs developed the concepts, such as climate stabilization, and climate change engineering. The United Nations Framework Convention on Climate Change (UNFCCC) was thus proposed more than two decades ago to provide a global platform to negotiate protocols for reduction of GHG emissions. Under the assumption of GW being dominantly due to GHG emissions, Kyoto Protocol was proposed almost two decades ago. Since then several amendments to the Kyoto Protocol have been brought forward with a common goal of GHG emission reduction by committing nations. Because of asymmetric emission of GHGs globally, concept of Carbon trading was coined. Pakistan, being a ratifying party to Kyoto Protocol, has currently several options to implement Carbon trading. Twenty third conference of parties to UNFCCC (COP23), expected to be held in Germany, in November 2017, provides an excellent opportunity for Pakistan to reiterate its commitment and to exercise its options to shape its sustainable economy for coming decades by taking advantage of asymmetric GHG emissions.

Keywords: *Carbon Dioxide emissions, Global Warming, Statistical Analysis, UNFCCC, Kyoto Protocol, Pakistan.*

1. INTRODUCTION

The objective of this review article is to present some statistics related to Carbon Dioxide (CO_2) emissions and global warming in the context of Pakistan. This would provide a background scientific reading for the forthcoming 23rd international meeting of parties to United Nations Framework Convention on Climate Change (UNFCC)/Kyoto Protocol (COP23/CMP13) being held in November 2017. The increased CO_2 emissions and associated global warming are currently evolving discourses in climate change science studies (see, for instance, Weart, 2015).

The available discourses on global and regional Carbon emissions are too numerous to be summarized in such a short review article. Furthermore, they are expanding at a rapid pace. Therefore, only selected and subjective topics have been addressed in this review article.

2. DOMINANCE OF CARBON EMISSION IN GREEN HOUSE GASES

The concentration of emitted CO_2 is the highest among the other Green House Gases (GHGs) (CH_4, N_2O, HFCs, PFCs, and SF_6) as suggested in the Kyoto Protocol. In fact, in recent decades, global CO_2 emission is higher by several orders of magnitude than the rest of above listed GHGs. A main concern with CO_2 is its somewhat uncertain but long staying time in atmosphere, resulting in a significantly bigger contribution to global warming as compared to other GHGs, such as CH_4 (Stocker, et al., 2013). The alarming rate of rising concentration of GHGs, in particular, the CO_2, is of concern both for scientists and policy-makers.

Since 1958, the results of CO_2 emission observations reported from Manua Loa observatory, Hawaii, USA, are considered to be representative of global Carbon emissions (Keeling, 1960; Keeling, et al., 1976). The time series of CO_2 emission is now commonly known as Keeling curve. Manua Loa is a barren lava field of an active volcano situated at 19°32' N, 155°35' W, and 3397 m above mean sea level, in the state of Hawaii in the Pacific ocean in USA. Although now the Carbon emission is measured at more than 100 locations, globally (Gurk, et al., 2008; Matsueda, et al., 2015; Sweeney, et al., 2015; see also http://www.esrl.noaa.gov/gmd/), including recent attempts to map the atmospheric content of CO_2 using remotely sensed data (Watanabe, et al., 2015). The global monthly CO_2 emissions have both regional as well as seasonal variability (Guo, et al., 2015).

3. RELATION BEWTEEN CARBON DIOXIDE EMISSION AND GLOBAL WARMING: CALLENDAR EFFECT

It is worthwhile to briefly touch upon these two topics and the possible connection between the two. Apparently, Guy Stewart Callendar, an English steam engineer, building upon earlier works, was the (first)

[#] In this article, CO_2 emissions and Carbon emissions are used interchangeably.

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† COMSATS' Science Ambassador in the field of Climate Change. This review is based on talk given under Science Diplomacy Programme.

one to systematically study the connection between Carbon emissions in the atmosphere, the absorption and emissions spectra of CO_2 in the atmosphere, and the global temperature rise (Callendar, 1938). A modern description of all of his works including a complete biography is available in Fleming (2007). Callendar i) showed that the anthropogenic contribution is higher than the natural CO_2 in the atmosphere and ii) included the impact of vertical thermal structure of earth, pressure broadening of line widths, the information that was not available to his previous research workers, while studying the absorptive properties of CO_2, and showed that the increase in the atmospheric CO_2 concentration of the atmosphere alters the altitude and thus raises the effective radiating temperature of the sky radiation reaching the ground. This is referred to as Callendar effect or the theory of GHGs.

Figure-1 displays the frequency distributions of emitted CO_2 (ppmv) concentrations and the northern hemisphere surface temperature anomaly, T (°C), and their scatter plot with a regressed fit indicating that a linear relationship between CO_2 and T accounts for 76% of proportion of variability, during the recent 50-year period (1961–2010). That is, more than half of the northern hemisphere warming may be attributed to the rise in emitted CO_2 concentrations. An exponentially regressed fit is found to explain somewhat less proportion of variability. The annual CO_2 emission data plotted in Figure-1 were obtained from Carbon Dioxide Information Analysis Center (CDIAC), Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, USA (http://cdiac.ornl.gov/). The anomaly based annual surface temperature dataset was obtained from Climate Research Unit at University of East Anglia, UK (http://www.cru.uea.ac.uk/). The presence of a linear trend and an oscillatory residual in the time series of emitted global concentration of CO_2 and surface temperature anomaly was also noticed for the same period. This is a statistical relationship only without taking into account any dynamics of mechanisms involved. More detailed statistical analysis of the relationship between the emitted concentration of CO_2 and T that takes into account the time ordering of the CO_2 data is also available (Sun and Wang, 1996).

In contrast to simple modeled instantaneous relationship between anomaly-based surface temperature and the CO_2 emissions, briefly mentioned above, it has already been noticed that the change in absolute surface temperature has a logarithmic response to CO_2 emissions, relative to a predefined baseline period (Callendar, 1938). The logarithmic response ensures saturation in change in absolute temperature as a result of increasing CO_2 emissions. Anderson, et al., (2016) provides a detailed historical description of Arrhenius' and Callendar's works including an analytic formula for the logarithmic response to CO_2 emissions following Callendar's earlier calculation. Considerable and wide ranging interest in the climate science community exists over this topic*.

In addition to statistical relationships between the emitted concentration of CO_2 and T, the climate model based relationships between the two are also extensively studied for the twenty first century (see, for instance, Wigley and Schlesinger, 1985; Friedlingstein, et al., 2006; Allen, et al., 2009; Matthews, et al., 2009; Raupach, et al., 2011; Stocker et al., 2013; MacDougall and Friedlingstein, 2015). The climate model based limits of CO_2 emissions to remain below the climate stabilization target of 2°C rise in surface temperature (Meinshausen, et al. (2009)).

4. CLIMATE STABILIZATION TARGETS

Climate stabilization is currently considered in terms of amount of atmospheric concentration of CO_2 to be limited or reduced. For instance, for a 2°C equilibrium global average warming, the Carbon emission needs to be between 370 and 540 ppmv, with the best suggested value of 430 ppmv (National Research Council, 2011). As of July 2015/July 2016, the monthly average CO_2 at Mauna Loa was 401.30/406.81 ppmv (for update see, http://www.esrl.noaa.gov/gmd/ccgg/trends/). A considerable change in a range of socio-economic factors occurs as a result of per degree rise in equilibrium global average temperature (Edenhofer, et al., 2014). These include, but are not limited to, crop yield decease, sea level rise, recurrent occurrence of severe floods and droughts, and hence change in climate, both at regional and at global levels. Because of the time lags among interacting components in the Earth's climate, as well as because of the longevity of CO_2 lifetime in atmosphere of Earth (30–95 years, according to one estimate), a time scale

* For a physical description of this logarithmic dependence, the reader is referred to a blog site maintained by Mrs. Clive Best (http://clivebest.com/blog/?p=2241), whereas for an analytic description, the reader is referred to an unpublished article by Harvey Lam (http://www.princeton.edu/~lam/documents/LamAug07bs.pdf).

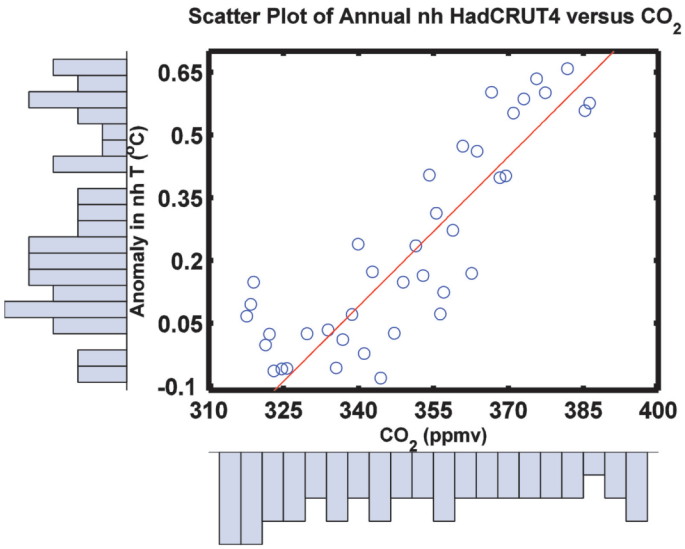

Figure-1: Bivariate Distributions of CO_2 Emissions (ppmv) and Northern Hemisphere Anomaly in T (°C), including their Scatter Plot During the Recent 50-year Period (1961–2010). The Continuous Straight Line is a Linearly Regressed Fit for the Paired Open Circles Values.

of centuries is involved to obtain climate stabilization and reversibility (see, for instance, Inman, 2008). This longevity estimate is based on the current understanding of Carbon cycle. This lag has led to the concept of transient and equilibrium warming. A consequence of this mechanism is that irrespective of when the concentration of CO_2 is reduced, global warming will continue for decades to centuries. This is not the case for other GHGs, for which the warming effect lasts for few decades only. In fact, a reduction of more than 80% in atmospheric concentration of CO_2 is required to stabilize the CO_2 concentration at century scale, at any time. The increase in global surface temperature also leads to change in extreme climate events, such as extreme precipitation events (Athar, 2014; Hegrel, et al., 2015).

5. UNFCCC AND KYOTO PROTOCOL

Given the above mentioned growing evidence in favor of rise in mean surface temperature, international concerns started shaping in the form of international discussion groups, especially at UN Headquarters in New York, USA, to address the causes of it. A multi government organization panel was thus formed, now known as IPCC in 1988 (Agrawala, 1998).

Kyoto Protocol was initiated in 1995 to address the issues related to global warming that were not covered by Montreal Protocol (UNFCCC, 2015). Montreal Protocol mainly addresses the concerns related to ozone layer depletion in the upper atmosphere. There are two key assumptions, upon which Kyoto Protocol is based upon. It is assumed that i) global warming is occurring, and that ii) Carbon emission is a dominant cause of it. Kyoto Protocol is a comprehensive 28 article document linked to UNFCCC, which commits its parties (as listed in its Annex-I) by setting internationally binding emission reduction targets. The main goal of the Kyoto Protocol is to constrain emissions of the main GHGs in ways that reflect underlying national differences in GHG emissions, wealth, and capacity to make the reductions. It is a legally binding document to its Annex I party countries. The Kyoto Protocol was presented and adopted in Kyoto, Japan, on 11 December 1997. The detailed rules of implementation of the Kyoto Protocol were adopted in Marrakesh; they are referred to as Marrakesh accord. After the condition that at least 55 members rectify it, which was met in 2005, its first commitment period started in 2008, and ended in 2012. Its second commitment period started in 2013 and will end in 2020. During the first commitment period, parties committed themselves to reduce GHG emissions to an average of 5% below 1990 levels (which was 354 ppmv). During the second commitment period, parties committed themselves to reduce GHG emissions by at least 18% below 1990 levels. Several amendments to Kyoto Protocol were made. These include adoption of Doha Amendment on 8 December 2012.

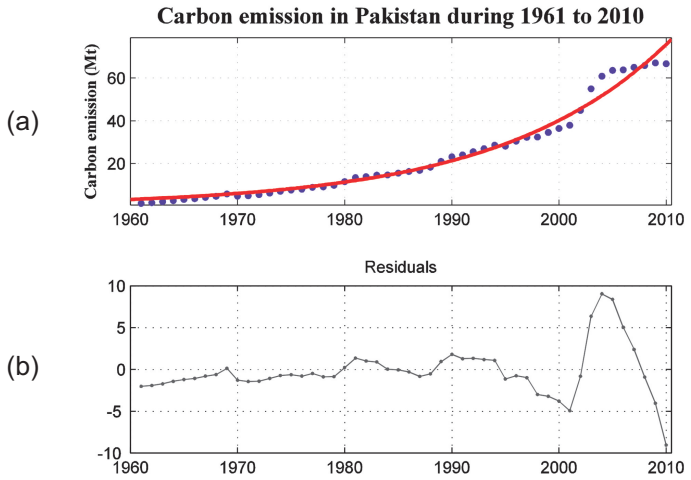

Figure-2: (a) The Gaseous Fuel Based Carbon Emission (Mt) in Pakistan during 1961-2010, the Solid Continuous Line Represents a Regression Fit. (b) the Residuals of the Regression Fit, Displaying an aperiodicity of Varying and Progressively Increasing Amplitude.

Considerable discussions are available on the definition and mechanisms of technology transfer in the context of Carbon trading, given the institutional capacity of the developing countries to capitalize on the technology transfer (Haselip, et al, 2015). Briefly, Kyoto Protocol offers the following three mechanisms to reduce CO_2 emissions:

i) International Emissions Trading (IET or EIT),
ii) Joint Implementation (JI), and
iii) Clean Development Mechanism (CDM).

The IET is meant for Annex II parties to Kyoto Protocol, those who have accepted targets for limiting or reducing the CO_2. The EIT, as set out in article 17 of the Kyoto Protocol, allows countries that have emission units to spare - emissions permitted them but not used - to sell this excess capacity to countries that are over their targets. The JI, as set out in article 16 of the Kyoto Protocol, is for those parties to Kyoto Protocol who have their own standards of reduction in CO_2, whereas the CDM, as set out in article 12 of Kyoto Protocol, is meant for developing countries, who have not yet set standards for reduction of CO_2. These mechanisms are based on the principle that no matter where the gases come from, the impact on environment is the same, and the reduction in emissions should come from the places where it will cost the least. Pakistan is a non-annex I party to Kyoto Protocol and has implemented the CDM mechanism (http://www.cdmpakistan.gov.pk).

6. CARBON EMISSION AND WARMING IN PAKISTAN: PAST, PRESENT AND FUTURE

Figure-2 indicates that the rise in Carbon emission (Mt) due to gaseous fuel consumption is almost exponential in Pakistan during 1961 to 2010. The annual CO_2 emission data for Figure-2 was obtained from CDIAC. A low amplitude oscillatory component can be seen in the residuals, with a gradual increase in amplitude after 1990. In this dataset, slight increase in 2003 and 2004 occurs and then a leveling off occurs. The data fits with an exponential function with 97% proportion of variance of data accounted for, and with an increasing rate of 6%/year.

According to Carbon emission inventory of Pakistan for 2008, the Carbon emission of Pakistan accounts for less than 1% of global Carbon emission. The 2008 inventory indicates that the dominant contribution in this Carbon emission by Pakistan is from CO_2, which is 54%, followed by CH_4, which is 36%. The energy sector is the largest single contributor to GHG emissions in Pakistan, which is nearly 51%, followed by the Agriculture sector, which is nearly 39%.

Figure-3 displays the interannual variability of surface temperature over Pakistan using observed as well as multi (climate) model-based datasets, both from AR4 and AR5 groups, for 1961–2010, following Asmat and Athar (2015). The observed (re-analysis based) gridded temperature dataset was obtained from a USA-based website (https://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html), and is abbreviated as NCR. In the AR4 group of models, the

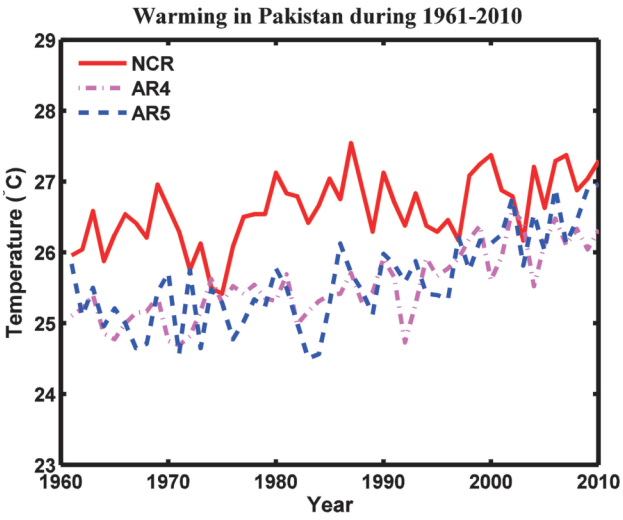

Figure-3: Inter-annual Variability of Surface Temperature (°C), Over Pakistan Using the Observed Gridded Dataset (NCR), and Using Two of the State-of-Art Atmospheric Ocean Coupled Climate Models (from AR4 and AR5). All Three Datasets Display an Increasing Linear Warming Trend

following coupled atmospheric ocean general circulation models were used: 20C3M and A1B versions of GFDL-CM2.0 and GFDL-CM2.1, whereas in the AR5 group of models, GFDL based models with representative concentration path way suggesting a CO_2 emission of 4.5 watt/m^2 by the end of twenty first century (RCP4.5) are employed. For validation details of GDFL based models over Pakistan, see Asmat and Athar (2015). All three temperature datasets were re-gridded to a common 2°x2° grid prior to analysis. The NCR data displayed more interannual variability relative to mean of climate models, both in AR4 and AR5 groups, with a linear warming trend of 0.17°C/decade with proportion of variation accounted for, R2=26.50%, whereas AR4 (AR5) based models displayed a linear warming trend of 0.25°C/decade (0.29°C/decade) with R2 = 56.10% (48.80%), respectively. Comparatively, this warming rate is less than half of that in Saudi Arabia, which is 0.60°C/decade with R2 = 65.00%, in recent decades (Almazroui, et al., 2012).

Figure-4 displays the spatial distribution of Carbon emission in the neighboring countries of Pakistan as of 2010, taken from CDIAC. The darker the color of a country on the map, the higher its Carbon emission. The highest Carbon emitters in the neighboring countries include Russian Federation (877 Kt), Iran (294 Kt), and China (197 Kt).

The Government of Pakistan presented its plans to reduce the Carbon emissions via a seven-point Intended Nationally Distributed Contribution (INDC) to COP 21, which was held in Paris in December 2015. This INDC is available from Ministry of Climate Change website cited in further reading, late in this review article. However, this 300-word INDC by Pakistan reflects more the need for preparation of a reliable national Carbon inventory so that quantitative estimates for Carbon reduction can be communicated by Pakistan in future. In contrast, among developed countries, USA suggested to achieve 26% to 28% reduction in CO_2 emission from all of its energy sectors by 2025 relative to 2005 levels, based on its national Carbon inventory.

An aim of COP21 was to propose a universal binding agenda on reduction of Carbon emissions. By now, 162 countries out of 196, have already submitted their INDCs to COP21/Paris 2015 conference secretariat. More than 180 countries producing more than 90% of global emissions had submitted their INDCs to COP21. Additionally, the commitments by non-governmental players, such as cities and regions were surprisingly quite numerous.

In general, the COP21 findings emphasized the requirements that all parties report regularly on their emissions and implementation efforts, and undergo international reviews. This includes the communication of new INDCs every five years, containing information necessary to track progress made in implementing and achieving their INDCs. Although, operational details of the new framework were left to be decided by future COPs.

Figure-4: Spatial Distribution of Carbon Emissions (Kt) in Asia Neighboring Pakistan as of 2010 (CDIAC-2015). Timor-Leste, Mongolia and Nepal are Among the Least Carbon Emitting Countries. Pakistan's Contribution is 66.7 Kt as Compared to India's 98.5 Kt. The Darker the Blue Shade, the Higher the Carbon Emission.

The COP22 was held in Morocco in November 2016. The aim being to enter into agreement for parties to start implementing the Paris Agreement reached during COP21. In general, COP22 reaffirmed the commitments laid out in COP21 as declared in Marrakech action proclamation, including the reaffirmation of USD$ 100 billion mobilization goal by Developed Country Parties, as well as a call for common vision for accelerating climate action. Other highlights include the development of progress tracker based on the goals set out in COP21.

7. ROAD AHEAD: COP23 AND BEYOND

The COP23 is expected to be held in November 2017 in Bonn, Germany, with the aim to assess the progress in achieving the targets for global CO_2-emission reduction agreed upon in Paris during COP21.

Based on the mitigation strategies proposed in INDCs submitted to COP21, Sanderson et al. (2016) have presented details of several idealized RCPs to achieve the 1.5° and 2.0° C warming targets by the end of 21st century, as a function of annual CO_2 emissions, relative to unmitigated baseline RCP8.5 (high emission scenario), and as a function of mitigation starting year. An ensemble of perturbed versions of the Integrated Science Assessment Model (ISAM) was used to assess the uncertainty in the idealized RCPs, under the assumption that intermediate complexity ISAM mimics well the RCP2.6 (low emission mitigation) scenario in the Coupled Carbon Cycle Climate Model Intercomparison Project (C4MIP) models. It was concluded that a 10% cut in GHG emissions by 2030 (relative to 2015) could likely achieve 2°C target with RCP2.6 level like negative subemissions (-1.5 Gt CO_2/yr)*. For a further discussion on these estimates, see Crane (2016).

The road ahead is not free from challenges for Pakistan. It has been brought to notice through several studies that considerable political will is required to overcome several culture based societal hurdles (Sher, et al., 2011). For instance, in the energy sector, the electricity generation is a selected societal sector where mitigation has to be implemented, as tentatively selected by Pakistan. Within this sector, challenges for environmental-friendly and low Carbon electricity generation include awareness barrier, economic barrier, financing barrier, institutional barrier, and policy and regulatory barriers.

8. CONCLUSIONS AND RECOMMENDATIONS

More awareness at grass-root levels is needed around the world about the adverse consequences of accelerated rates of emission and then accumulation of Carbon in the atmosphere so that more systematic and coherent efforts can be made and sustained at policy-making levels. Specifically, for Pakistan, it is imperative to:

- Get propriety rights for Green technology;
- Eradicate poverty and establish Green industries

* For details of RCPs, see http://www.pik-potsdam.de/~mmalte/rcps/.

that are low on Carbon emissions;
- Develop and maintain more comprehensive national GHG inventory.

These must start with a strong political will towards sustainable environment. More efficient Green technologies are being created along with changing political dynamics both locally and regionally. This calls for a constant dialogue among various national stakes holders to come up with more comprehensive and feasible Carbon reduction plans at short, medium and long-term time scales.

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FURTHER READING

Excellent sources of updated information on science (Stocker, et al., 2013), and policy aspects (Edenhofer, et al., 2014; Field, et al., 2014; Barros, et al., 2014), of global as well as regional CO_2 emissions and likely associated warming are presented in fifth annual report (AR5) of Intergovernmental Panel on Climate Change (IPCC). For a more detailed description of the topics covered here, the reader is referred to the above excellent sources. For updated information on global Carbon measurements, see www.esrl.noaa.gov/research/themes/carbon/. Furthermore, for Pakistan specific information, several sources are available; these include but not limited to websites by Government of Pakistan, such as Ministry of Climate Change website (www.mocc.gov.pk). In particular, a vast amount of analyzed information on various aspects of climate change issues is continuously provided by governments and semi-government organizations globally, including World Bank, non-profit organizations, as well as electronic media based community sites (see, for instance, http://www.rmets.org/paris_climate_communique). The interested reader is referred to these mainly online sources of updated information: the level of discussions vary considerably in these updated sources of information, ranging from expert opinions in internationally refereed journals to amateur discussions and from subject specialists' deliberations to beginner level illustrative conversations. All cited references and sources of information in this brief review article thus can only be considered as representative ones rather than exhaustive ones.

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